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LXIX. A STUDY OF THE BIONOMICS OF THE COMMON RAT FLEAS AND OTHER SPECIES ASSOCIATED WITH HUMAN HABITATIONS, WITH SPECIAL REFERENCE TO THE INFLUENCE OF TEMPERATURE AND HUMIDITY AT VARIOUS PERIODS OF THE LIFE HISTORY OF THE INSECT.

BY

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LXIX. A STUDY OF THE BIONOMICS OF THE COMMON RAT FLEAS AND OTHER SPECIES ASSOCIATED WITH HUMAN HABITATIONS, WITH SPECIAL REFERENCE TO THE INFLUENCE OF TEMPERATURE AND HUMIDITY AT VARIOUS PERIODS OF THE LIFE HISTORY OF THE INSECT.

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SECTION I. INTRODUCTION.

THIS research was undertaken at the instance of the Advisory Committee for the investigation of plague in India, its object and scope being to ascertain the effects of varying conditions of temperature and humidity on the species of fleas associated with rats and man: to trace if possible the critical temperatures and humidities which allow of or prevent their breeding, and further to ascertain if possible in which of the several stages of the flea's life history, whether as ova, larvae, pupae or imagines, the effects of extreme conditions of drought and heat proved most fatal. It was also expected that evidence might be forthcoming as to a probable aestivating or hibernating stage, in which these species could tide over periods when heat, drought or cold prevent active breeding and cause the flea population to fall to a minimum, or to disappear entirely, as in the case of *Ceratophyllus fasciatus* in the Punjab, between the months of May and November.

The methods and apparatus employed together with general remarks with regard to rearing, habits and life history of the flea, are treated as a separate chapter at the close of the introductory remarks. The experiments on breeding were of two kinds, firstly a series of rearing experiments from the egg onwards under different conditions, and secondly definite tests carried out separately on the several stages. The former as well as the latter have, however, been arranged under the various headings of eggs, larvae, cocoons and adults for the sake of convenience in tabulation. The numbers employed in each experiment in addition to the date should render the continuation of the individual experiments in the subsequent stages easy to follow.

The species used for these experiments were chiefly *Pulex irritans* *Ceratophyllus fasciatus*, and *Xenopsylla cheopis*. Some work was also carried out with *Ceratophyllus gallinae* and *Ctenocephalus canis*, as well as with *Ctenocephalus felis* on one occasion, but difficulties in feeding these species on their proper hosts in captivity have prevented a plentiful supply of eggs being obtained, and restricted the scope of the experimental work. One set of experiments was also performed with *Leptopsylla musculi* in the summer of 1912, in order to study the conditions determining emergence from cocoons and the length of the resting period.

SECTION II. SPECIES AND ORIGIN OF THE FLEAS USED IN THE EXPERIMENTS.

Ceratophyllus fasciatus (Pl. XXVII, figs. 1 and 2). Some 30 adults were received from Prof. Minchin's stock (Lister Institute), which originated from fleas captured on rats trapped near Sutton Broad Laboratory, Norfolk, and a similar number were received from Prof. Nuttall's Laboratory at Cambridge.

Pulex irritans (Pl. XXVIII, figs. 1 and 2). A start was made with about a dozen specimens captured at Loughton and, although a few specimens were received from a friend in Hampshire, it is very doubtful if there is any infusion of blood from this source in the stocks used for the experiments, as the survivors of the specimens received were very feeble.

Ctenocephalus canis (Pl. XXIX, figs. 1 and 2), *Ctenocephalus felis* (Pl. XXIX, figs. 3 and 4) and *Ceratophyllus gallinae* are all of Loughton race.

Leptopsylla musculi (Pl. XXVII. figs. 3 and 4) were obtained from the Lister Institute.

Xenopsylla cheopis (Pl. XXVIII, figs. 3 and 4). Tubes containing living larvae of this species forwarded from India in the autumn of 1910 did not produce sufficient fleas to give an effective start, but specimens obtained subsequently by Dr Boycott from an English source have resulted in strong stocks, and the experiments have been performed with individuals of this race.

It is possible, even probable, that experiments on stocks from restricted localities may not give evidence of the full range of variation of a species, which might enable it to adjust itself to the varying conditions of climate experienced in its geographical distribution. The known variation of habit in other insects, which meet needs called forth by slight differences within small areas, suggests this is likely to be the case[1]. On the other hand the wide range of variation in duration of the cocoon period, found present in the stocks of *C. fasciatus* and *P. irritans*, would afford ample opportunity for selective action when taken in conjunction with their powers of rapid multiplication. It would be simple in the face of a climate with an extreme range of conditions, such as is experienced in some parts of India, for a race of *C. fasciatus* to be produced in which rapidly emerging individuals were in the majority at one period of the year and those having a long delayed period of emergence constituted the bulk of the flea population at a succeeding period. It seems probable that this is the explanation of the recorded complete disappearance of *C. fasciatus* during the hot months in the Punjab (*Journal of Hygiene*, Vol. VIII. No. 2, May 1908, p. 241).

In the case of *C. fasciatus* breeding cages were started in July 1910, but it was not until the autumn of that year that a sufficient stock was available for the production of ova in the numbers required, while with *P. irritans* it was only with the commencement of spring 1911 that egg laying was on a satisfactory basis. In consequence, the early experiments which deal with very small numbers but cover as wide a range of conditions as possible are to be regarded in the light of an attempt to ascertain the direction in which future experiments, with larger numbers, might most profitably be carried out. They also afforded an opportunity of improving the methods of treatment and feeding. Many of the results are of considerable interest and, as in the case of resting cocoons, are valuable in themselves, in spite of the small numbers of fleas employed; but others are unsatisfactory, if not deceptive, for the coincidence of food tests with seasonal changes renders it uncertain as to whether the results are due to one cause or the other.

There was no evidence of a definite resting phase during the earlier experiments but rather of a general variability dominated by temperature. With larvae of *C. fasciatus* taken from the cages during the

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[1] *E.g. Papillio machaon* is single brooded in Norfolk and double brooded in Cambridgeshire.

Winter 1910–11, there was, however, a distinct tendency to rest in the cocoon stage, and this was in great measure irrespective of the range of experimental conditions.

In one instance broods were ruined owing to a too drastic reduction in the humidity of an incubator; in another to the use of a sample of sand which proved inimical to the larvae; the cause of this was suspected to be the presence of sodium chloride.

It has been thought best to include all the experiments without exception, however clear the cause of failure might appear, in the hope that future workers in this new field of research may find the results of some value.

SECTION III. APPARATUS AND EXPERIMENTAL METHODS EMPLOYED.

(*a*) *Range of external conditions; temperature and humidity.*

The experiments were carried out chiefly in four incubators, two of which were maintained at 75° F.[1], but with differing degrees of humidity, and a similar pair at 85° F.

In addition use was made of a cellar, the Laboratory cupboard and one situated next to a chimney flue, the fire being unused between the months of May and September.

Since December 1910 use has also been made of an empty beehive in the garden.

INCUBATORS. For clearness the incubators have been designated by their temperature and their condition as regards humidity, thus: incubator 85 Wet; incubator 85 Dry; incubator 75 Wet; incubator 75 Dry. Records of temperature and humidity were taken twice daily, except on Sundays, when as a rule only one reading was made. These are set out in tabular form below, pp. 460–2, and graphically shown in Charts 1 and 2. A few records had to be discarded owing to the Wet bulb thermometers being out of order. The conditions aimed at were to keep one at 85° F. with humidity at ·70; one at 75° F. humidity ·75; one at 85° F. humidity at ·55 to ·60, and one at 75° F. with humidity at ·50 to ·55.

The degree of humidity in the air is according to Glaisher—"The ratio of the quantity of vapour present in any volume of the air to

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[1] All temperature readings are on the Fahrenheit scale.

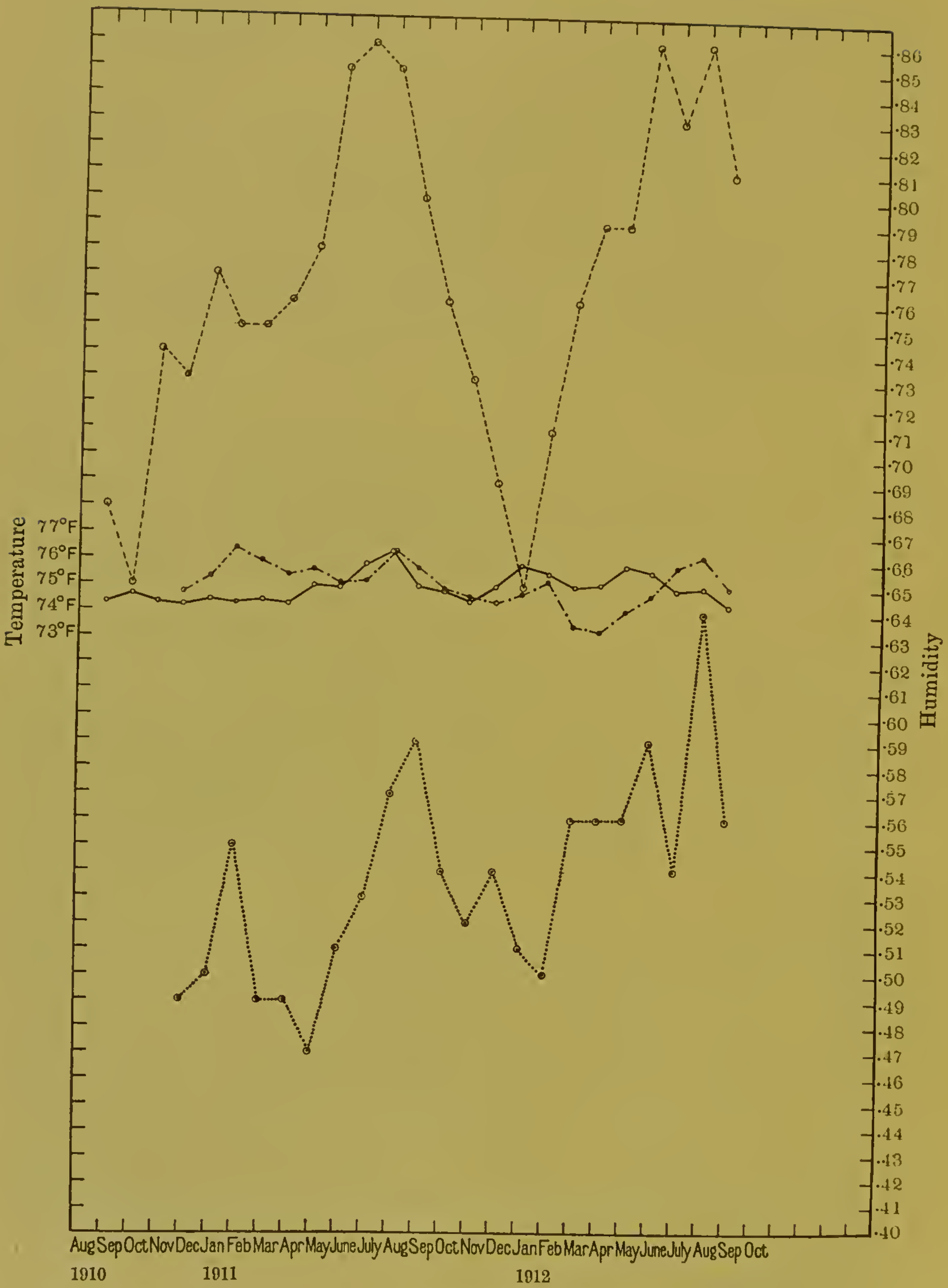

Chart 1.

Incubator 75 Wet. Temp. ——— Humidity - - - - - -
Incubator 75 Dry. Temp. -·-·-·- Humidity ·········

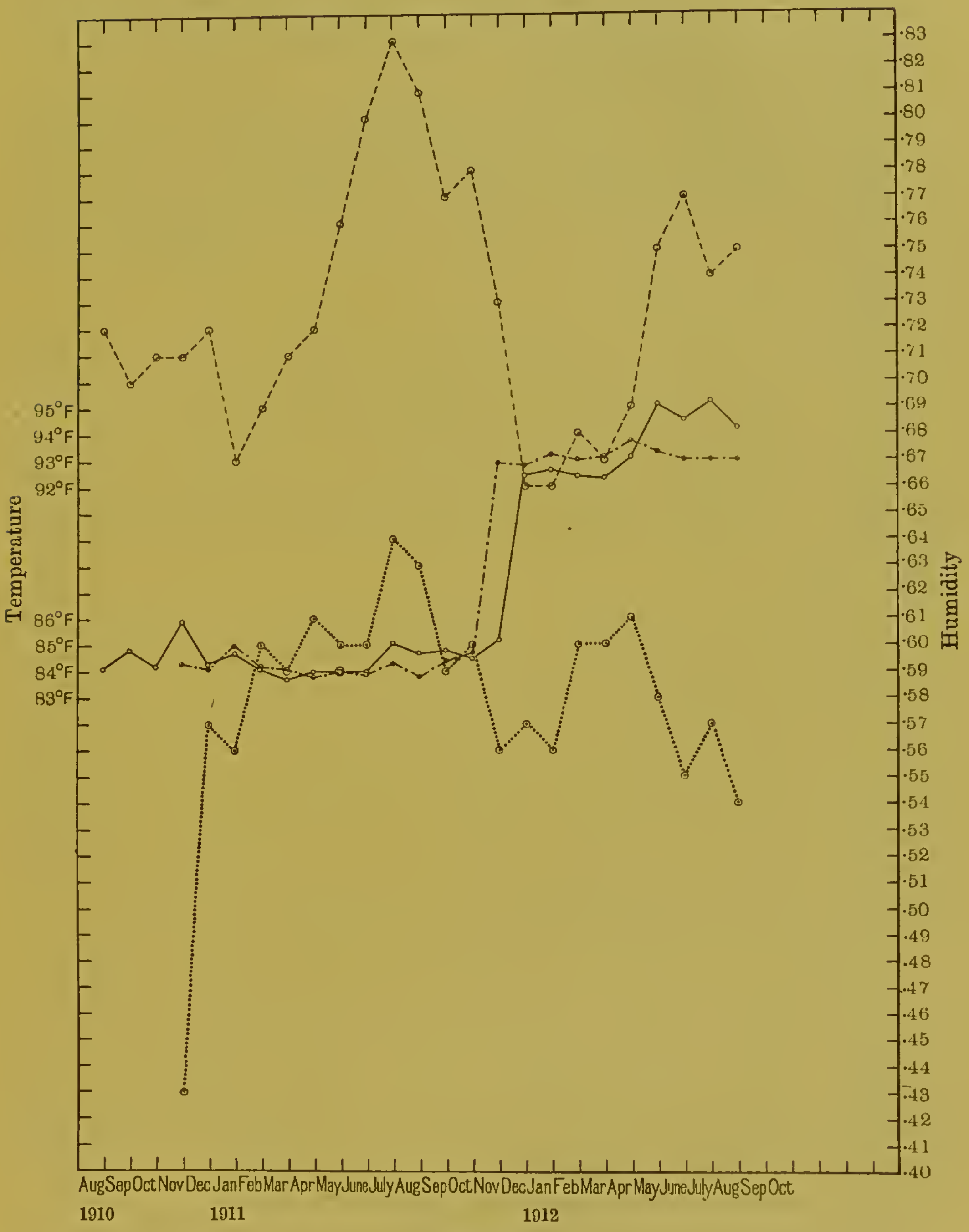

Chart 2.

Incubator 85/95 Wet.	Temp. ———	Humidity - - - - - -
Incubator 85/95 Dry.	Temp. -·-·-·-·	Humidity ········

the quantity which would have been present in the same volume, had the air been completely saturated." The readings of the "Dry" and "Wet" bulb thermometers were taken and the percentage of humidity obtained from Glaisher's tables.

During November 1911 the temperature of the two hot incubators, 85 Wet and 85 Dry, was raised to 93° F. or thereabouts, as it was desired to make certain tests under conditions of greater heat; from the time of change onwards they are referred to as 93 Wet and 93 Dry—a few experiments that had been started at the lower temperature being finished at the higher.

Except during the hot summer and cold winter months, it will be seen that the averages are roughly in the neighbourhood of the desired figures. From the contrasted breeding experiment dealing with *P. irritans, X. cheopis* and *C. fasciatus* (Table XXV) it will be seen that the rise in humidity of 85 Dry and 75 Dry to ·63 and ·59 respectively in these two incubators was not sufficient to permit of any larvae surviving, so that the experiments were not really interfered with from this cause.

Laboratory Cupboard. (Chart No. 3.) This is a rather cool and very draughty place with a cement floor, on a side of the building that never gets any direct sunshine on it. Its temperature tends to be rather lower than that of a room without a fire and its humidity during cool wet autumn or winter weather is well in excess of the incubators; it tends to be drier than the incubators during the spring and summer months. A glance at the experiments (Tables XVII and XXI) will show that, while the conditions are next to impossible for *C. fasciatus*, they are successfully surmounted by a percentage of *P. irritans.*

The Cellar. (Chart No. 4.) This gives an even range of temperature seldom differing by more than one or two degrees from night to day, and ranging from an average of 44° F. in February to 64° F. in August 1911 (four degrees higher than the summer temperature of the previous year). Its record of humidity is even more stable—being practically constant at ·91 to ·93. It has a bricked but uncemented floor and probably represents fairly well the conditions of cellarage prior to the free use of cement in modern buildings.

The conditions were found to be very favourable to all stages of the flea's life history with the exception of egg laying, and possibly hatching —save during the warm months—but development of the larvae is slow, so slow in some instances that it is a question whether the final failure of larvae to spin, as in experiment 6th October 1910 with

P. irritans, may not have been due to their food deteriorating during the long delay and their ultimate starvation.

WARM CUPBOARD. (Chart No. 5.) As will be seen from the tables, the range of conditions is not very wide, apart from the extremes of the summer of 1911. Normally the temperature is between 60° F. and 70° F. and its humidity not far from ·55 to ·60. Its conditions seem to be even less favourable for the hatching of eggs than the low humidity incubators 85 Dry and 75 Dry, and at least equally fatal to larval development.

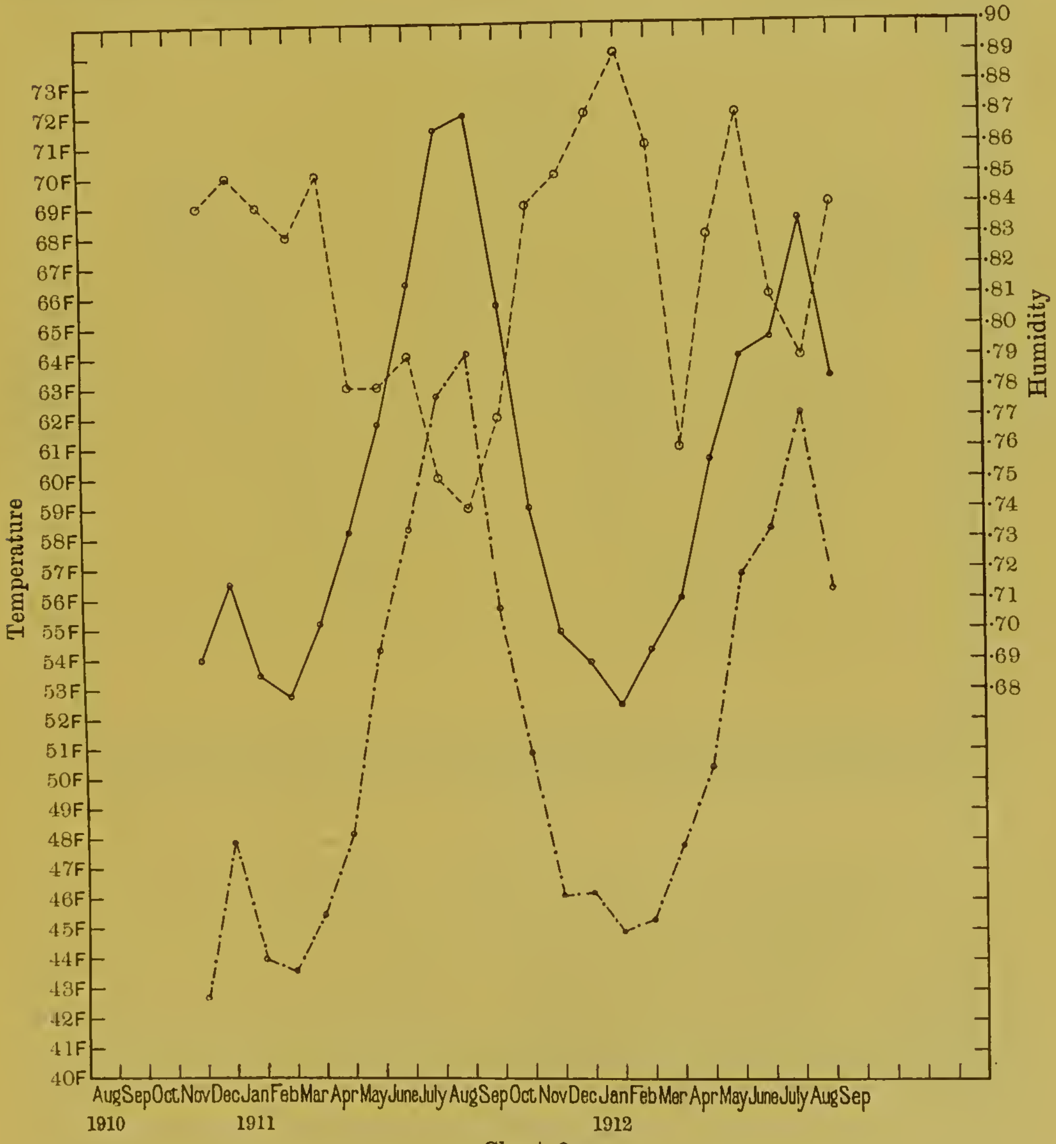

Chart 3.

Laboratory Cupboard. Temperature Max. ——— Humidity - - - - - - -

Min. -·-·-·-·

Full records of temperature and humidity were not kept for the cupboards and cellar until the autumn of 1910; there is also a gap from April to July 1912, when the readings of "Wet" and "Dry" bulb thermometers were not taken in the cellar, as the latter instrument was in use elsewhere. The previous record, however, over a long period, and that for the months of August and September 1912, had remained constant so that the estimate of ·93 is considered near enough for all practical purposes.

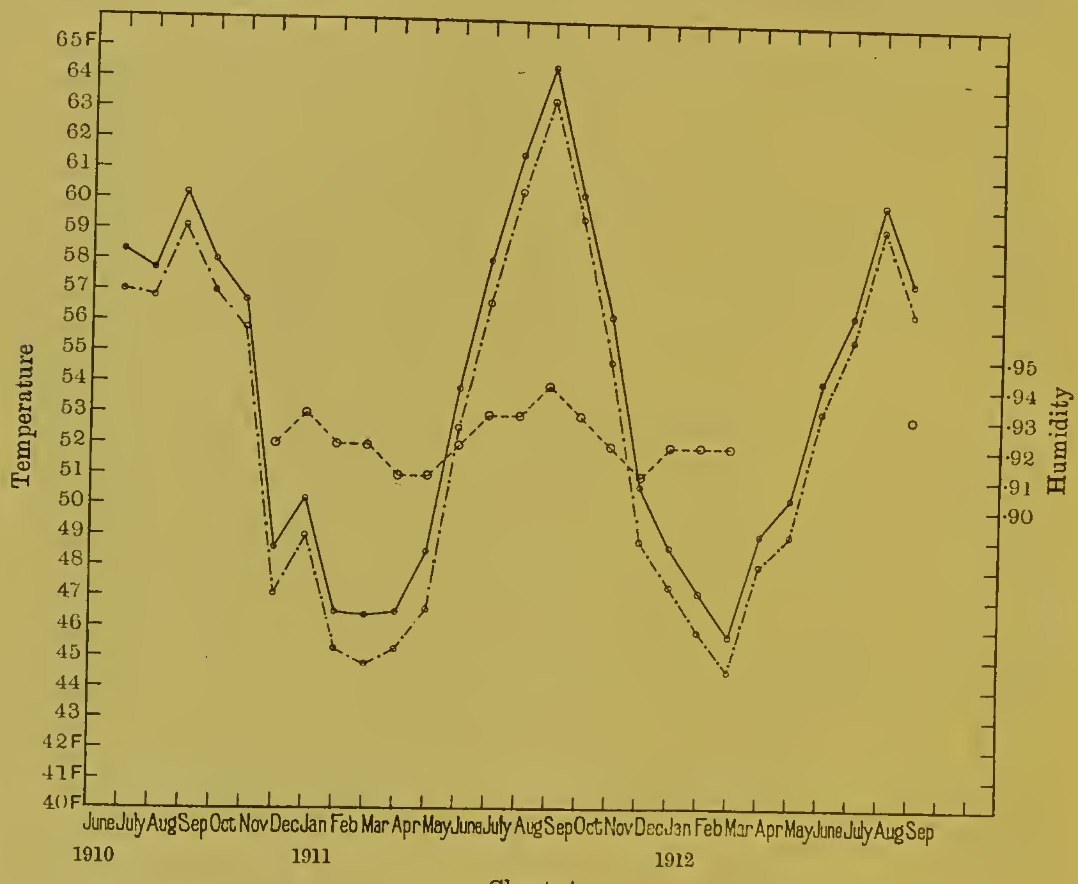

Chart 4.

Cellar. Temperature Max. ———— Humidity -------
Min. -·-·-·-·

BEEHIVE. (Chart No. 6.) This was installed as a control to test the influence of the natural extremes of night and day temperatures, chiefly with regard to the cocoon stage. No humidity records were taken as it was thought that these were unlikely to yield trustworthy comparison with the conditions elsewhere unless taken at frequent intervals. As might be expected, the results obtained by its use varied according to the weather conditions prevailing, but evidence is afforded that the larvae of some species can withstand considerable cold, even when newly hatched.

In order that the records of humidity might be as accurate and reliable as possible, Dr Martin kindly devised an air circuit past the wet bulb thermometers in the incubators in order to guard against the error involved when readings are taken in a nearly still atmosphere. The readings were in every case the minimum obtained after working the air circuit illustrated on p. 459. There still remains, however, the fact that the mortality in such a place as a house cupboard is far higher in comparison than in the incubators. It is suggested that this is

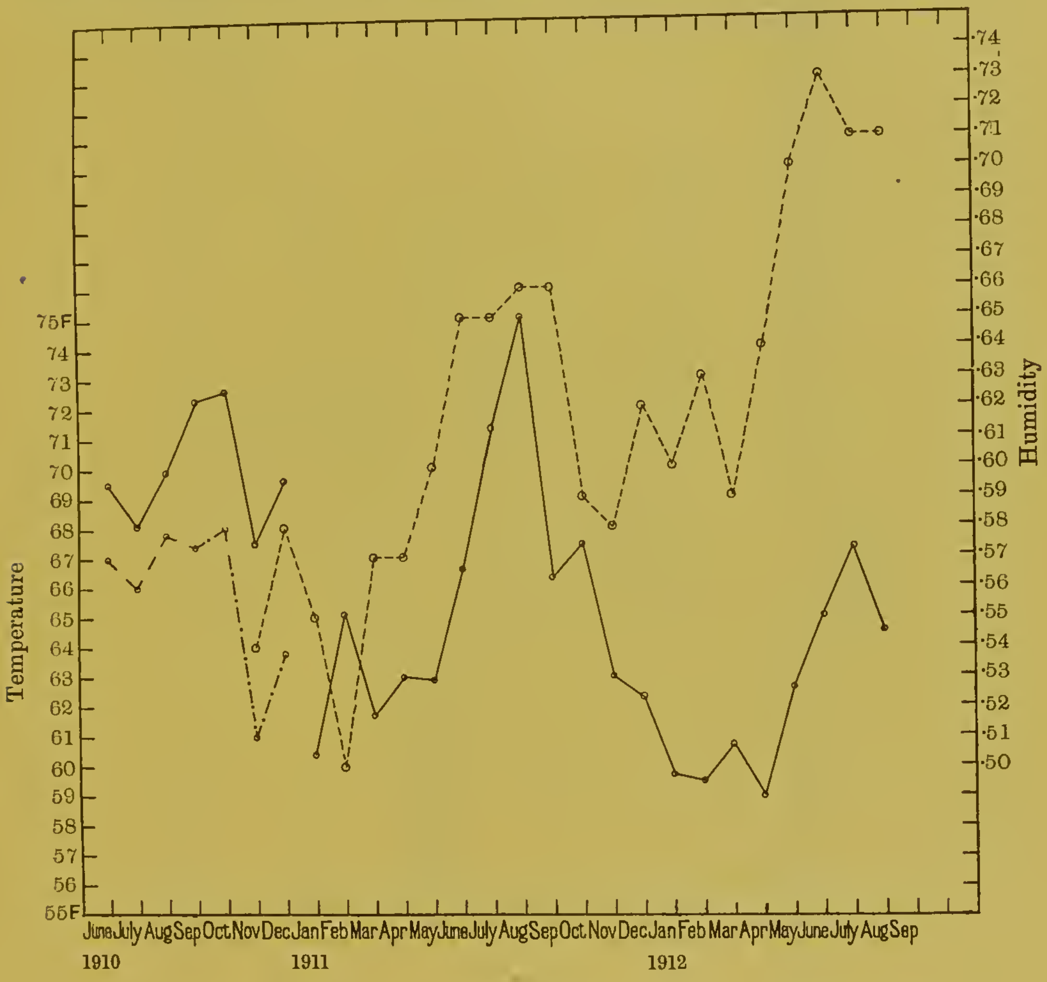

Chart 5.

Warm Cupboard. Note up to Dec. 1910 Max. and Min. records were made, after that date readings are of the "dry" bulb of the Hygrometer.

Temperature Max. ———— After Dec. 1910 Dry bulb of Hygrometer ————
Min. -.-.-.-.-. Humidity ------

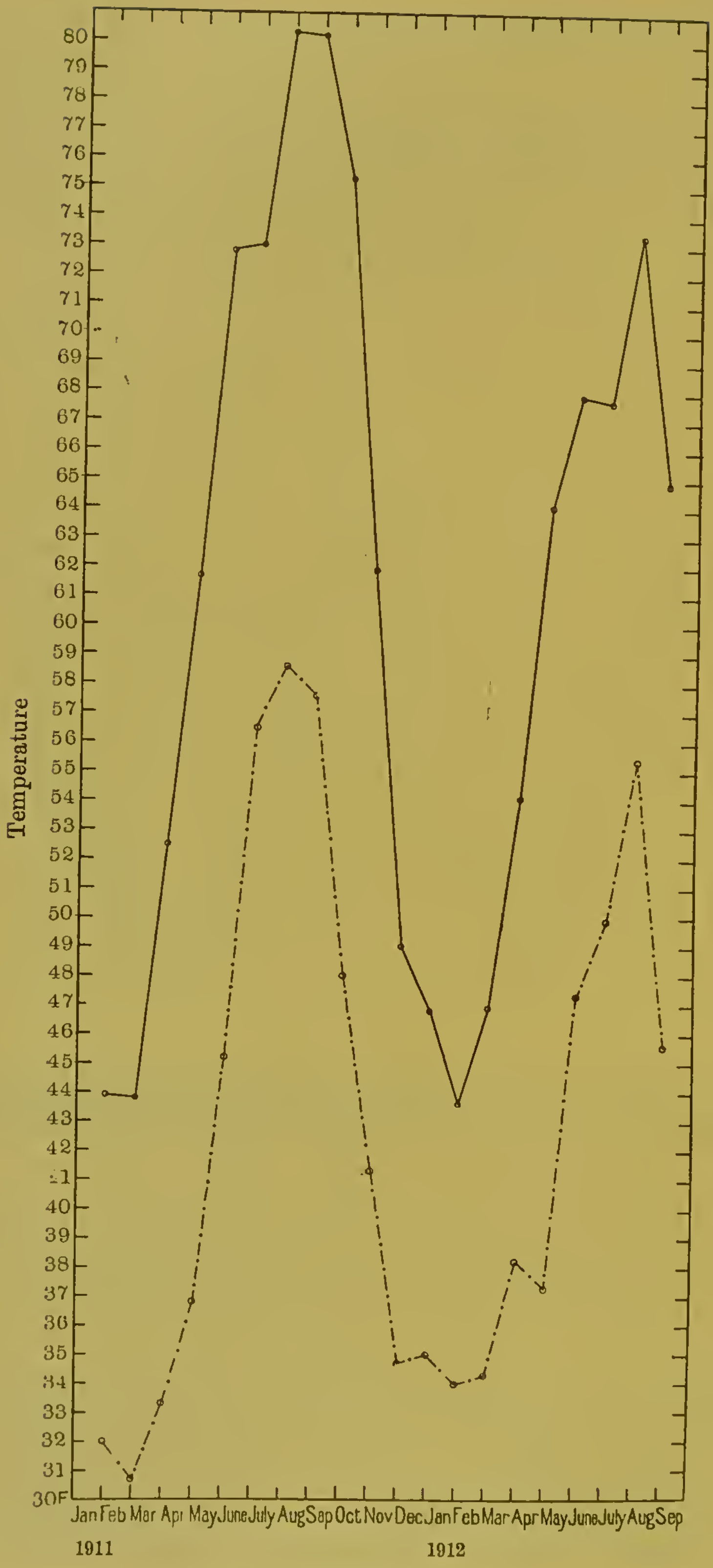

Chart 6.

Beehive. Temperature Max. ——— Min. -·-·-·-·

due to the inequality of the humidity in the latter. The small amount of current in an incubator possibly allows of "pockets" of moist air to remain undisturbed in the receptacles in which the larvae are reared. Possibly the moisture given off by the larvae themselves may produce an envelope of humid air which enables them to escape the desiccation that would inevitably occur in a more draughty situation[1].

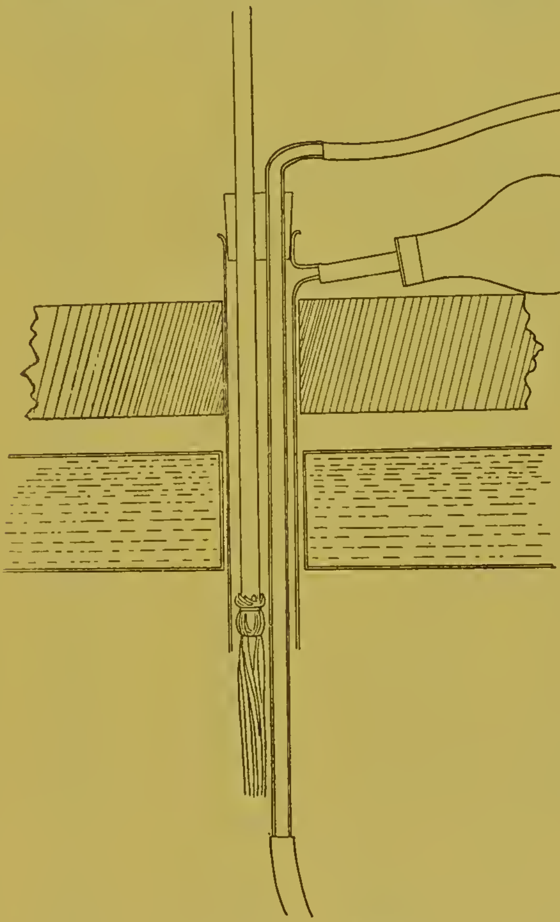

Fig. 1.

In contrasting results this possibility should be borne in mind, as it seems possible that all the incubator humidities should be regarded as higher than the actual readings, in comparison with other situations. Even with incubators having a wide range of ventilation adjustment and a water tray subdivided so as to allow of a varying area of exposed water surface, it is impossible, during the summer, to maintain a steady percentage of moisture in the air for more than a few hours or days together, as all the conditions are swayed by external changes. In the winter and autumn, especially at night, when a clearing sky results in a ground frost, there is a rapid fall in the amount of moisture in the outside air drawn into the incubators, and when hard frosts set in it is difficult to maintain sufficient humidity to enable the larvae to escape destruction, even with the ventilators shut down and wet cloths hung in the interiors.

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[1] For example, in the case of the newly hatched larvae trials in incubator 75 Wet (see Table X); the average length of life is only half as long in July as during the cold months. This is apparently due to a less stagnant atmosphere in the former case. It is usual to keep the ventilator more widely open during the summer as this can be done without any corresponding fall in humidity.

Incubators. Monthly Averages of Humidity and Temperature.

Month 1910	Incubator 85° Wet		Incubator 75° Wet		Incubator 85° Dry		Incubator 75° Dry	
	Temp.	Hum.	Temp.	Hum.	Temp.	Hum.	Temp.	Hum.
Aug.	84·1	·72	74·3	·68				
Sept.	84·8	·70	74·6	·65				
Oct.	84·2	·71	74·3	·74				
Nov.	85·9	·71	74·2	·73	84·3	·43	74·7	·49
Dec.	84·3	·72	74·4	·77	84·1	·57	75·3	·50
1911								
Jan.	84·7	·67	74·3	·75	85·0	·56	76·4	·55
Feb.	84·1	·69	74·4	·75	84·2	·60	75·9	·49
March	83·7	·71	74·3	·76	84·1	·59	75·4	·49
April	84·0	·72	75·0	·78	83·8	·61	75·6	·47
May	84·0	·76	74·9	·85	84·0	·60	75·1	·51
June	84·0	·80	75·8	·86	83·9	·60	75·2	·53
July	85·1	·83	76·3	·85	84·3	·64	76·3	·57
Aug.	84·7	·81	75·0	·80	83·8	·63	75·7	·59
Sept.	84·8	·77	74·8	·76	84·4	·59	74·9	·54
Oct.	84·5	·78	74·4	·73	84·7	·60	74·6	·52
Nov.	85·2	·73	75·0	·69	92·9	·56	74·4	·54
Dec.	92·4	·66	75·8	·65	92·8	·57	74·7	·51
1912								
Jan.	92·6	·66	75·5	·71	93·2	·56	75·2	·50
Feb.	92·4	·68	75·0	·76	93·0	·60	73·5	·56
March	92·3	·67	75·1	·79	93·1	·60	73·3	·56
April	93·1	·69	75·8	·79	93·7	·61	74·1	·56
May	95·1	·75	75·6	·86	93·3	·58	74·7	·59
June	94·5	·77	74·9	·83	93·0	·55	75·8	·54
July	95·2	·74	75·0	·86	93·0	·57	76·2	·64
Aug.	94·2	·75	74·3	·81	93·0	·54	75·0	·56
Sept.								

(*Readings twice daily.*)

NOTE. A 3 Nov. 1910 20 Temp. and 14 Humidity readings only.
F 3 ,, 20 ,, 14 ,, ,, ,,

Laboratory Cupboard.

	Number of readings	Temperature		Humidity
1910		Max.	Min.	
Nov.	23	54·0	42·7	·84
Dec.	31	56·5	47·9	·85
1911				
Jan.	31	53·5	44·0	·84
Feb.	28	52·8	43·6	·83
March	31	55·2	45·5	·85
April	30	58·2	48·2	·78
May	31	61·8	54·3	·78
June	30	66·4	58·3	·79
July	31	71·5	62·7	·75
Aug.	31	72·0	64·1	·74
Sept.	30	65·7	55·7	·77
Oct.	31	59·0	50·9	·84
Nov.	30	54·9	46·1	·85
Dec.	31	53·9	46·2	·87
1912				
Jan.	31	52·5	44·9	·89
Feb.	29	54·4	45·3	·86
March	31	56·0	47·8	·76
April	30	60·6	50·4	·83
May	31	64·0	56·8	·87
June	30	64·6	58·3	·81
July	31	68·5	62·1	·79
Aug.	31	63·3	56·3	·84
Sept.				

Cellar.

	Number of readings	Temperature		Humidity
1910		Max.	Min.	
May	19	56·0	54·1	
June	28	58·3	56·9	
July	31	57·7	56·8	
Aug.	30	60·2	59·1	
Sept.	30	58·0	57·0	
Oct.	30	56·7	55·8	
Nov.	30	48·6	47·1	·92 (27 readings of humidity)
Dec.	30	50·2	49·0	·93
1911				
Jan.	31	46·5	45·3	·92
Feb.	28	46·4	44·8	·92
March	31	46·5	45·3	·91
April	30	48·5	46·6	·91
May	31	53·9	52·6	·92
June	30	58·1	56·7	·93
July	31	61·6	60·4	·93
Aug.	31	64·5	63·4	·94
Sept.	30	60·3	59·5	·93
Oct.	31	56·3	54·8	·92
Nov.	30	50·7	48·9	·91
Dec.	31	48·7	47·4	·92
1912				
Jan.	31	47·2	45·9	·92
Feb.	29	45·8	44·6	·92
March	31	49·1	48·1	·93 (estimated)
April	30	50·3	49·1	·93 (estimated)
May	31	54·2	53·2	·93 (estimated)
June	30	56·4	55·6	·93 (estimated)
July	31	60·1	59·3	·93 (estimated)
Aug.	31	57·5	56·5	·93 (27 readings of humidity)
Sept.				

Warm Cupboard.

1910	Number of readings	Temperature Max.	Temperature Min.	Humidity
May	18	71·9	67·1	
June	28	69·5	67·0	
July	31	68·1	66·0	
Aug.	31	69·9	67·8	
Sept.	30	72·3	67·4	
Oct.	30	72·6	68·0	
Nov.	30	67·5	61·0	·54 (27 readings of humidity)
Dec.	28	69·6	63·8	·58 (31 readings of humidity)
1911		Dry Bulb		
Jan.	29	60·4		·55
Feb.	27	65·1		·50
March	31	61·7		·57
April	29	63·0		·57
May	30	62·9		·60
June	30	66·6		·65
July	28	71·3		·65
Aug.	30	75·0		·66
Sept.	30	66·3		·66
Oct.	29	67·4		·59
Nov.	30	63·0		·58
Dec.	30	62·3		·62
1912				
Jan.	31	59·7		·60
Feb.	29	59·5		·63
March	31	60·7		·59
April	30	59·0		·64
May	31	62·6		·70
June	30	65·0		·73
July	31	67·3		·71
Aug.	31	64·5		·71
Sept.				

Beehive.

1910	Number of readings	Temperature Max.	Temperature Min.
Dec.	3	50·0	29·0
1911			
Jan.	31	43·9	32·0
Feb.	28	43·8	30·7
March	31	52·5	33·3
April	30	61·7	36·8
May	31	72·8	45·2
June	30	73·0	56·5
July	30	80·3	58·6
Aug.	31	80·2	57·6
Sept.	30	75·3	48·0
Oct.	31	61·9	41·3
Nov.	30	49·0	34·7
Dec.	31	46·8	35·0
1912			
Jan.	31	43·6	34·0
Feb.	29	46·9	34·3
March	31	54·1	38·2
April	30	64·1	37·3
May	31	67·9	47·3
June	30	67·7	49·9
July	31	73·4	55·4
Aug.	31	64·9	45·6
Sept.			

(*b*) *General arrangement and management of breeding cages.*

For rearing rat fleas I have used a slightly modified form of the cage designed for the infection experiments of the Advisory Committee illustrated in the *Journal of Hygiene*, Vol. VI. No. 4, Sept. 1906, Plate IV. The alterations consist of somewhat enlarging the cage and making the inner cage larger in proportion to the outer. Several different sizes have been tried, the most convenient is: Outer glass cage 10″ × 10″ × 18″, inner wire cage 8″ × 8″ × 8″, neck or entrance tube 5″ in diameter by 3″ deep. The pan 9″ × 9″ × 1″ deep. Copper or brass wire gauze is preferable to iron as it does not rust. In place of the tin lid a wire gauze cover keeps the cage drier and sweeter, and a muslin cover[1] may be used over this to ensure that no fleas escape. The cover of the outer cage is of muslin tied round the neck or entrance tube and fastened to the glass sides with glue. It is well to use some cement that can be softened, as portions of the cover have to be removed occasionally. The floor, pan and all, should be covered with about one to one and a half inches of silver sand or sawdust. Sand should be washed and then baked to make certain that it neither contains any salt nor harbours mites or other harmful organisms.

A single large rat, or two small ones, may be kept in a cage of this size without its getting too humid under normal atmospheric conditions. Occasionally, say at monthly intervals, a quantity of the sand and the rats' bedding should be shifted to the space between the wire cage and the glass and returned the following month. Under exceptional circumstances it is necessary to remove a portion of the sand and bedding entirely, in order that it may be slowly dried in some deep walled receptacle; it may then be returned with its fauna of larvae and fleas.

In cages for breeding *C. fasciatus* it is well to supply the rat with some pieces of cloth or felt as bedding; this very much facilitates the collection of both fleas and their larvae which will be found wandering over and through the felt respectively.

As regards *X. cheopis*, cloth bedding for the rat does not offer the same advantages for obtaining fleas and their larvae. The former are usually to be found in the greatest numbers on the rat itself or in the sand, while the larvae are usually distributed through the sand and are seldom seen on the cloth. Cocoons are, however, to be obtained in numbers spun on buried or partially buried pieces of cloth placed between the outer and inner walls of the cage.

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[1] The best material to employ is what is known by drapers as "Nainsook."

FOOD FOR THE RATS. Bread and milk, given in small pans, was the only food used in the cages during the first year. It was adopted in preference to grain, bran, etc., as a precaution against mites, which are frequently present in corn chandlers' stores. A better method adopted later is to give some oats, a piece of new bread and a drink of milk daily.

With mice I am informed that the proper diet is mixed oats and hemp seed and a small piece of bread which, after being wetted and squeezed to remove the superfluous moisture, is left in the cage for an hour or so and then removed. This method has proved quite successful for mice, but for rats more liquid is essential.

The grain and seed should be heated before use to kill off any mites or other organisms it may harbour. Although we were able to keep our cages free from mites for many months, they eventually became infected, possibly by way of the animals when changes took place. At least two species were present—the more numerous being one of the vegetable-feeding Tyroglyphidae that is very commonly associated with grain stores. The other was a species of *Cheyletus* closely allied to, if not identical with, *Cheyletus eruditus*. This mite probably lives chiefly on the vegetable feeding species, but will undoubtedly attack and destroy flea larvae, a specimen having been caught in the very act.

It is questionable, however, if this species is very harmful in the cages when the other mites are numerous, as the latter will be much easier prey for the *Cheyletus* than the frantically active flea larvae. When the flea larvae are moulting, the case may be otherwise, and, should the *Cheyletus* be present to a large extent, or the vegetable feeding species of mites be absent or present in small numbers only, serious mortality of the flea population might occur.

(c) *Methods employed in rearing fleas and experimenting with them.*

1. OBTAINING AND HATCHING EGGS. To obtain ova of *Pulex irritans*, the adults are kept in one-inch cardboard boxes with glass bottoms[1],

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[1] In each incubator or other place used for experiment a jar of sand is kept in which are buried the boxes containing fleas for egg laying or cocoons awaiting emergence and the tubes of adult fleas for longevity tests. Glass tubes containing newly hatched larvae whose length of life without food is being determined should be partially buried in the sand to prevent any condensation of moisture in the tube.

This method was instituted so as to render the conditions of the experiments on adults more natural, the habit of the flea being to hide away in crevices, corners, etc., where more equable conditions of temperature and humidity are likely to obtain than elsewhere.

The result proved satisfactory, as the mortality among the fleas put into boxes for egg laying was greatly reduced, and the average number of eggs laid was increased.

the lid replaced by a cover of fine silk gauze (chiffon) securely tied on. A loose ring of dark cloth is placed round the inside of the box to give the fleas foothold, and this also proves very convenient for the removal and counting of the eggs that are laid on it. If the card of the box is stained with methylene blue or other dark colour, the finding and counting of those eggs that are laid off the cloth are facilitated. This box is nested in one of the next larger size for security and only removed for feeding, when the gauze is placed against any convenient skin surface. One quarter of an hour per day is sufficient time for feeding, but larger numbers of eggs are laid in response to more food. The fleas must be shifted to a fresh box or the ova removed every three or four days to prevent any larvae that may be hatched escaping through the mesh of the gauze.

Rat, dog or other fleas are collected from the host or its bed and put into boxes. Up to 50 females and the due proportion of males are put into a one-inch glass-bottomed box, and for greater numbers a box of one and a quarter inch diameter is used.

The box is prepared in the same way as for *P. irritans*, but the gauze cover may be omitted (for method of boxing fleas, see p. 464). The boxes containing the fleas are buried in the sand pots mentioned in footnote on p. 464. To induce the fleas to lay freely the boxes are kept in a humid atmosphere at a temperature of 70° to 75° F. The fleas are left in the boxes for 24 hours and then returned to the cages.

It is not so necessary to bury *P. irritans* as it is *C. fasciatus* and *X. cheopis*, but in the hotter incubators or during cool weather it is advisable. *X. cheopis* does not lay freely unless the cage containing both fleas and their host is kept at about 70°—75° F.

HATCHING. Eggs are best left where they are laid if this is possible, for, though they can usually be moved by the use of a moistened camel's hair brush with safety, it is not always possible to avoid injuring them, as they occasionally become quite firmly attached in spite of the fact that no cement is used by the female when they are laid.

The powers of abstinence on the part of the newly hatched larvae renders it practicable to leave the hatching box without food supply; the young larvae are then collected day by day by inverting the box in the mouth of a glass tube, when, after gently tapping, they fall into the bottom of the tube. A warm humid atmosphere is best to ensure a speedy emergence from the egg. Cool conditions lower, and hot and dry ones raise, the percentage of failures without proving so absolutely fatal to the ova as they are to the larvae.

2. FOOD AND TREATMENT OF LARVAE. Glass tubes, entomological boxes and card jars have been used as receptacles for rearing larvae. Glass tubes one and a quarter to one and a half inches in diameter give good results for small numbers, but they are liable to condense moisture if the air is humid or subject to large temperature variations. Glass-bottomed boxes did not give satisfactory results and are not very convenient, as with humid conditions the cardboard lids swell and become too tight. "Mono Service" card cream jars are light, unbreakable, and being made of compressed waxed card, are not absorbent, and at the same time do not condense moisture so readily as glass. Most of the experiments were carried out in half-pint jars of this description. A cover of thin muslin, fastened by an elastic band, served to keep out dust and prevent any rapidly developed fleas from escaping without seriously checking free interchange of temperature and humidity.

Food (for a general discussion on the food of flea larvae, see Section IV, subsection 2).

In the experimental work five separate diets were tried :—

(1) Blood-soaked rag, which is first to be recommended. Any slaughter-house can supply a mutton-cloth dipped in blood, and if this be wrapped in paper and put in a dry situation it will keep indefinitely and may be cut into snippets as required. This formed the chief food used in the experiments, and is designated, for brevity, B.S. Rag.

(2) Flea faeces, in which case the gauze covers to boxes in which fleas have been fed, are very convenient provided they are well spotted and blotched with the blood and dejecta voided during and subsequent to feeding. This food, referred to as "flea faeces," although the blood ingested was human, seemed to suit *C. fasciatus*, *X. cheopis* or *P. irritans* equally well.

(3) Dead flies. A few experiments were made with *Musca domestica* and *P. irritans*. The diet proved a moderate success, but required renewing constantly, and the time expended in catching flies, together with shortage of supplies in late autumn, prevented further trials. The fact that the cocoons are very difficult to find when flies are used makes this food quite unsuitable for some sections of experimental work.

(4) Bran gave very poor results for feeding *C. fasciatus* when used in the small quantities that it is convenient to work with if close observation is required before the fleas actually emerge. It is also open to the same objection as the dead flies as regards the difficulty of finding the cocoons.

(5) Rat Faeces. These gave very poor and unsatisfactory results with *C. fasciatus*. Crushing or chopping the faeces was tried and improved matters somewhat. Larvae in some instances fed well, and the percentage of cocoons was high, but the actual numbers of *C. fasciatus* reared were small. Larvae of *P. irritans* and *X. cheopis* succeeded much better on this food, which is a decided improvement on the flies and bran although the cocoons are not easy to find. Possibly under natural conditions, when a fresh supply is continually available, rat faeces may be a more important article of diet than the experimental evidence suggests.

Cover for the larvae. A small quantity of fine sand or other finely divided material should be placed at the bottom of the receptacles used for rearing larvae; about $\frac{3}{4}$ of an inch is sufficient, the food being mixed in with the sand. It is not necessary to use sand with bran, dead flies, or some other foods, and larvae have been reared on dried blood alone in a glass tube. Its use is, however, a necessity when rearing in a cage, as pointed out in the Reports of the Plague Commission (*Journal of Hygiene*, Vol. VIII. Chap. XXIX. Section 1), and is a convenience when rearing apart from the host, as it renders the finding of cocoons and their removal much easier. The sand or other material used ought always to be dry enough to fall grain by grain; it is detrimental when wet enough to cling.

Humidity. When rearing in very dry places a local humidity may be attained by placing at the bottom of the receptacle a disc of blotting-paper with a tag projecting above the sand; this tag can be wetted at intervals. The method of placing damp blotting-paper *above* the sand or a wet muslin cover to the tube or jar may be pursued. The sand itself should on no account be damped. The adjustment of this moistening, having regard to the local conditions of temperature, humidity and air circulation, makes all the difference between 100 % mortality in the first two days and the successful rearing of adult fleas, but too much or too little moisture may be equally fatal (compare tables and note the effect of moistening in incubator 75 Dry and 75 Wet, also between 85 Dry and 85 Wet).

Urine, as compared with distilled water, appears to be a more effective damping agent. Possibly the salts it contains retain the moisture and develop a pocket of moist air in the receptacle used, while with distilled water the desiccation is more complete. While admitting that the evidence for this last opinion is none too clear, there seems no doubt whatever as to the main issue of the beneficial effects of moistening generally in a dry atmosphere.

METHODS OF HANDLING. To collect individual larvae from the dust and rubbish of an animal's bed or nest is a slow task. By using a series of wire or muslin sieves the process may be much quickened; an ordinary wire document basket makes an excellent sieve for the first stage; small boxes with the bottoms replaced by fine mosquito netting and fine veil netting can then be used, only fine dust, larvae and eggs will be left in the pan. Much of the fine dust can afterwards be gently blown away. The best method of collecting larvae from dust or sand that is too heavy to be disposed of by winnowing is to spread the sand or dust thinly over a black or dark-coloured card and pick the larvae out with a fine moistened sable or camel's hair brush. Flea-larvae are usually very conspicuous, for such small objects, owing to their frantic activity, but occasionally may be missed as they lie still in a stiff stretched-out position or coiled up watch-spring fashion. Under these circumstances they are difficult to see, especially when small and coiled. It is best to leave the sand undisturbed for a few minutes and then re-examine, as they usually renew their activity after a short rest.

To test the length of life without food of freshly hatched larvae they were placed in small corked glass tubes, three-eighths of an inch by two inches, with a few scraps of blotting-paper to afford them foothold and cover. Coloured blotting-paper renders observation and counting easier. A subsequent method was to use a little fine sand and to plug the tube with cotton-wool; under these circumstances it is necessary to keep the tube upright.

3. OBTAINING AND TREATMENT OF COCOON STAGE. In treating the cocoon as a definite stage, convenience alone has been followed.

To obtain cocoons for experiment, full sized larvae are sorted out from the cages, breeding jars or the host's bed as the case may be. They are placed in a receptacle containing fine sand or dust and a supply of food and kept in a humid atmosphere at 70°—75° F. The cocoons must be removed daily from the receptacle if their subsequent history is to be at all closely followed; they are therefore removed to a one-inch glass-bottomed box and buried in the sand pots. For as the cocoons are naturally buried beneath dust or litter, or spun in crevices, it is an obvious precaution to bury the box in which they are kept if fair results are to be obtained.

4. CONTROL AND TREATMENT OF ADULTS. TRANSFERENCE OF FLEAS. For shifting, transferring or sorting fleas the use of a large pan with a white glazed surface, as recommended in the report of

the Advisory Committee (*Journal of Hygiene*, Vol. VIII. No. 2, p. 256, May 1908), was adopted.

For dealing with *P. irritans* a much deeper pan is necessary than for the rat fleas; it must also be wide, as otherwise the hands and arms of the operator prevent a clear view of the bottom being obtained. An enamelled iron "chef" bowl is suitable, but it should be ten inches to a foot deep, for *P. irritans* can jump at least a foot even from the slippery take-off afforded by an enamelled pan, and experience has shown that it can jump on to the clothing of a person stooping over the pan although unable to clear the rim. *Ct. canis* and *C. gallinae* are also good jumpers and require a deeper pan than either of the rat fleas. The jumping habit soon falls into abeyance, however, when the fleas are kept in small boxes and fed.

All jars, tubes or boxes in which larvae are being reared or cocoons kept, should be opened after being placed on the bottom of the pan, and in changing from box to box the same precaution ought to be followed. To collect fleas from the pan, an ordinary test-tube and a small camel's hair brush are all that is required. If the test-tube be held with its mouth in front of the flea, tilted at a slight angle so that the upper rim is above the insect, it will usually hop into the tube; the brush may be used to expedite matters or to aid refractory specimens to take a right direction. In case it is desired to collect *P. irritans* in boxes, the fleas being already in the pan, the box with cloth lining ready for their reception is dropped mouth downwards over first one and then another; each flea covered usually crawls or jumps on to the cloth lining without delay, so that boxing is not a lengthy process. When the required number are covered, a piece of fine silk gauze (chiffon) is placed over the upturned lid of the box at the bottom of the pan. The box is quickly lifted, fitted over its own inverted lid and gently forced down so that it does not quite shut. Thread can then be tied round the crack between the shoulder of the box and the lid. The lid may be removed, leaving the fleas securely imprisoned in a box with a glass bottom and a gauze cover in place of, or in addition to the lid. The process is somewhat easier if a loose fitting lid is kept specially for the process of fitting the gauze.

A more rapid method of boxing, useful for example in egg-laying experiments, is to first collect the required number of fleas in a tube and then to place in the pan a box prepared with cloth lining as described above. The lid of the box is slightly lifted and the fleas are shot in by a rapid tilt of the tube and the lid closed immediately. With most fleas a little practice makes one deft enough to perform the operation so that few, if any, have time to escape. In the case of *P. irritans*, however, this frequently happens.

The method of storing in gauze-covered boxes described above as specially suitable in case of *P. irritans* is applicable for dealing with any species of flea that it is desired to test in regard to its aptitude to feed on man. It can also be adopted for feeding tests on other mammals, provided that their fur is closely cropped on the area of application. Feeding fleas from boxes is not without its advantage in other ways than that of convenience, for there is no danger of their escape or destruction by the host while feeding, a point of considerable importance if the number of specimens is small.

It has not been found possible to feed captive fleas on either the domestic cat or dog with the time at our disposal for this purpose. The dog was willing, but too anxious to play, while the cats were indignantly and successfully hostile.

With a tame rat the matter was easy and it was found quite unnecessary to secure the rat. By holding it beneath the left hand, head to wrist, with the two forefingers along its back and the box containing the fleas held with the right hand against the clipped patch above the tail, it was possible to give undisturbed feeds of from five to ten minutes and repeat as desired.

To test the length of life of fleas unfed under conditions as favourable as possible, the adults are put into small paper tubes, made of filter paper rolled round a penholder and secured with thread tied round them. The ends of these tubes are carefully blocked with plugs of cotton wool wrapped in fine gauze; the gauze is necessary to prevent the fleas from being lost in the plug. The tubes are buried in the sand pots previously described and kept in the places where the experiment is to be made.

A second method is simply to place the fleas in a small card jar with sand at the bottom; the fleas burrow in the sand and some species appear able to survive longer under these conditions than in tubes, for example, one specimen of *C. fasciatus* lived 95 days and one of *C. gallinae* 127 days. *X. cheopis* is also favoured by this method, but to *Ct. canis* and *P. irritans* it is of no advantage.

SECTION IV. GENERAL OBSERVATIONS ON BIONOMICS OF FLEAS.

1. EGGS (Plates XXX and XXXI). As might be expected, the general effect of cold or cool conditions is to slow down or prevent egg laying. In case of both *P. irritans* and *C. fasciatus* however it is possible to induce them to lay at any time by changing them in a warm moist atmosphere (about 75° F., humidity about ·70). While *P. irritans* is the more responsive of the two, in neither case do the number of eggs laid under these conditions reach the summer average.

With *X. cheopis* the response to incubator treatment during the winter months is but slight; very few ova are obtained by removing females from the cages and placing them in an incubator at 75° F. for 24 hours. It appears necessary for egg production by this species that their host should be living in a warm atmosphere.

Ct. canis certainly lays under suitable conditions apart from season, as I have taken larvae from a dog's bed, indoors, as late as December.

C. gallinae is possibly more fixed in seasonable habit than the other species as regards egg laying. I have fed a number during the autumn months on myself, but, although kept constantly at a temperature of 75° F. except when feeding, no eggs were laid until spring.

2. LARVAE (Plates XXXI and XXXII). Rösel von Rosenhof reared fleas from the egg more than 150 years ago, and found that the larvae did not, as some supposed, feed on rotten wood. He discovered that they would feed on the bodies of their dead parents and could be reared on dead flies. The imminent failure of this source of diet with the oncoming of winter caused him to seek for another food. He made trial of the blood of some pet doves and proved that the larvae could be successfully reared on this food. No doubt—as pointed out in Report XXIX. Section I. *Journal of Hygiene*, Vol. VIII. No. 2, May 1908, pp. 236 and 237—fleas may be reared on many kinds of organic matter if in a state of sufficiently fine division and fairly dry. The experience gained in the course of the present work, however, suggests that Rösel was very near to giving them their correct food and that the mainstay of the larval diet is the faeces of the adult fleas.

It may be that the necessity for this diet in case of larvae of a particular species depends upon the closeness of the association between the parent and the host fed upon. Fleas being chiefly, if not exclusively, nest or lair parasites, it is not surprising to find that the larvae should utilise as food the rich store of organic matter in suitable condition for assimilation that is afforded by the droppings of their parents.

It is an interesting speculation as to how far the adult's habit of wasteful feeding is the direct outcome of selective action, making a special provision for the larval food supply[1]. The habit of sucking to such excess that some of the intake has to be voided is not restricted to fleas; instances are recorded of species of the Hymenoptera and Lepidoptera acting in the same way.

The other conditions provided by the nest or lair of the host in nature are also ideal for the flea larvae, or, to put it in other words, the larval requirements are adjusted to those that are most likely to obtain where the eggs are dropped. The necessary conditions of warmth and humidity are provided by the host's body, while the provision of bedding and careful choice of a dry situation all fit in with the needs of the larval stage of the parasite. When the host leaves its nest or lair the temperature and humidity fall together, but, so far as observation goes, a fall in temperature will only have the effect of slowing development; a low humidity, however, if prolonged, will be fatal even when accompanied by low temperature.

P. irritans would appear to have diverged from the other nest-breeding fleas in respect of the sensitiveness of its larvae to external conditions; possibly the progressive civilisation of its host has forced it to become more adaptable. Larvae of this species were successfully reared under circumstances that proved fatal to *C. fasciatus* (see Tables XVI and XXI), and, for example, were able to feed satisfactorily on crushed rat faeces when the larvae of the latter species failed. Probably the trend of selective action has been in the direction of producing a race of *P. irritans* able to feed on any possible rubbish in out-of-the-way corners. Undisturbed breeding places in such immediate vicinity to its host as to receive any appreciable quantity of the parental faeces would become gradually rarer as cleanliness and comfort succeeded to the crowding and filth of primitive conditions.

Experiments carried out with *P. irritans*, *X. cheopis*, *C. gallinae* and *Ct. canis* show that there are three larval instars, two of the three moults taking place while the larvae are in the active stage—the third skin being cast within the cocoon during the metamorphosis to the pupal condition. So far the number of individuals of each species followed up is small, and it is not possible to say if any variation in the number of larval instars occurs. It seemed quite possible that the very small males of *X. cheopis*, which are not infrequent, might have one instar less, but no evidence of this has been forthcoming.

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[1] It is very noticeable to what an extent sick animals are attacked by fleas; after death their fur may be found full of dried faeces of these parasites, as though the fleas not only had an instinct, like that of Dugald Dalgetty in Scott's *Legend of Montrose*, for a full meal—not knowing when they might get their next—but were desirous of making sure of the future of their species by bequeathing a rich store of food for their larvae.

The heads of several larvae in each stage were measured and gave the following approximate ratios :

Ct. canis	1st	·16 mm.	*C. gallinae*	1st	·16 mm.
	2nd	·18 mm.		2nd	——
	3rd	·22 mm.		3rd	·28 mm.
X. cheopis	1st	·14 mm.	*P. irritans*	1st	·18 mm.
		·16 mm.		2nd	·24 mm.
		·20 mm.		3rd	·28 mm.

When reared in cages, the situation chosen by the larvae for spinning varies considerably between *C. fasciatus* and *X. cheopis*. Those of *X. cheopis* may be found like those of *L. musculi* spun on fragments of cloth, etc. given to the host for bedding. With *C. fasciatus* the cocoons are chiefly in the sand or at the bottom of the cages, seldom or never on the cloth.

3. COCOONS (Plates XXXIII and XXXIV). The cocoon is an oval envelope of silk (in the case of *C. fasciatus* which may often be more aptly described as of cement), spun by the larva, its exterior being covered with sand, dust, or any small fragments of dry material that are available. These fragments are not worked into the fabric, and it is probable that the larva collects them and attaches them together with a few silk threads and then proceeds to thicken the interior of this loose case with further accretions of gummy silk from the inside. Not infrequently the cocoon will be spun against the side or bottom of the rearing receptacle, the larger particles of sand, etc. being utilised for choice.

The cocoon of *C. fasciatus* varies from a flimsy structure composed of a few silk threads holding together grains of sand or other material, after the fashion of a string bag, to a hard, strong case, in the manufacture of which a much greater quantity of silk must be used. This forms a dense, firm lining of a yellow or brownish colour to the cocoon, which in extreme cases is almost like thin horn. Cocoons of *C. fasciatus* are easier to open than those of the other species dealt with, owing to the brittle character of the silk used.

P. irritans spins a quantity of soft white silk when well fed, and its normal cocoon is tough and soft.

The cocoons of *X. cheopis* are tougher and softer than those of *C. fasciatus*, and have more in common with *P. irritans* in the matter of shape as well as of texture.

Cocoons of *Ct. canis* are in appearance and texture nearer to those of *P. irritans* than to those of *C. fasciatus*. Those of *C. gallinae* have little resemblance outwardly to the cocoons already mentioned, being for the most part of pure silk, strong, soft and dense, pale brown in tint, and just transparent enough to allow of a decision as to their being empty or occupied. They are fastened to and spun amongst the material of which the nest is formed although the sand, etc. is not so firmly adherent to the fabric of the cocoon as in the case of the other species reared. The larvae of *C. gallinae* will, however, in sand produce cocoons very similar in appearance to those of *C. fasciatus* although not so hard.

Within these cocoons the larva lies doubled into a loop with some space to spare, although the acute bend in the body suggests discomfort; after pupation there is considerable space unoccupied. There is some doubt whether in the different species the extensive periods of rest which occur within the cocoon are larval or imaginal. The pupal period appears to be comparatively short, not more than a few days, so far as it has been possible to ascertain, and it seems probable that, once the pupal state is entered into, it must be carried to a conclusion without interruption. It was at first thought that the removal of pupae from their cocoons would be necessarily fatal, but this does not seem to be the case[1]. Resting larvae of *C. fasciatus*, as well as pupae of this and other species, have been taken from their cocoons and subsequently produced normal imagines. It is, however, likely that the normal course of development may be thwarted and a tendency to further rest be curtailed by removal, and it is improbable that such disturbed larvae could resist dry or otherwise unfavourable conditions. Certainly no instances of any continued delay in pupation have occurred in case of artificially opened cocoons.

RESTING COCOONS OF *C. fasciatus*. There seems good reason to think that the hard, strong types of cocoon commonly made by larvae of *C. fasciatus* are associated with the aestivating—hibernating or resting—habit; all grades, including the extreme, may be present in the same batch reared under precisely similar conditions. In some batches the resting tendency was found to be noticeably stronger than in others (Note November 1911, in the monthly cocoon series, *C. fasciatus* (Table

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[1] In a few instances naked pupae have been found in the cages; probably the larvae had been disturbed whilst spinning.

XXXIII)). While the evidence is not conclusive that these hard cocoons are always associated with lying over, and the frail ones with prompt emergence, still in a majority of cases this would seem to be the position of affairs (see Experiment with Hard and Soft Cocoons). It is easy to understand how desiccation may be long withstood in the impervious horn-like envelopes. The chances of injury and attack, either by parasites or predatory insects, is certainly lessened by the strength of the cocoons, although it is not easy to see that even the more flimsy cocoons are in much danger from parasites penetrating.

4. ADULTS (Plates XXVII–XXIX and XXXI). EMERGENCE FROM COCOONS. All the species dealt with so far have the habit of clinging to a cocoon after emergence and the flea may be passed over as it will sometimes remain quiescent, even after shaking the tube or box in which the cocoons are kept. On the other hand, any disturbance, however slight may be followed by emergence. It is also a fact that, when cocoons are opened for examination, they are found to contain living fleas far too often for it to be reasonably supposed that they are all chance occasions in which opening has happened to coincide with emergence. This supports the conclusion that the fleas are normally in the habit of resting, at any rate for a short period and possibly for many days, before emergence, unless some disturbance gives warning of the approach of a possible host.

P. irritans has the habit of shamming death, by lying on its side with the legs drawn up close to its body. It was at first thought that this habit was confined to the human flea, but continued observation has proved that the other species dealt with share the habit, with the exception of *X. cheopis* only, in which it has not yet been observed. No doubt, as in the case of other insects, the sudden change from rapid movement to complete immobility is most puzzling to a pursuer and a most effective method of escaping danger.

DANGER FROM HOST. Observation suggests that rats, dogs and cats frequently take considerable pains to rid themselves of fleas, especially on their first assault. It is noteworthy that rat fleas do not attack indiscriminately, that is to say, they pick out special points of vantage, *X. cheopis* making for the shoulders, neck and chest or for a spot beneath the forelegs[1]. *C. fasciatus* has a favourite spot just above the tail. A number of *C. gallinae*, however, did not show any discrimination in their attacks on a rat.

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[1] It will be remembered that in Part III of the Report published in the *Journal of Hygiene*, Vol. VI, No. 4, Sept. 1906, pp. 465–6, this preference of *X. cheopis* for the cervical region was noted.

PERIODIC BREEDING. The results of cocoon experiments, see p. 534, both as regard *P. irritans* and *C. fasciatus*, afford evidence of the existence of a seasonal habit as regards the emergence of both species; and in case of *Ct. canis*, *C. gallinae*, *L. musculi* and our English stock of *X. cheopis*, the evidence is even stronger. With *Ct. canis* and *C. gallinae*, however, the habit is probably in the process of modification in the direction of continuous reproduction in response to the domesticated character of its hosts.

In nearly all insects seasonal habits are strongly ingrained, owing to the direct and powerful effects of climatic conditions on their constitution; with parasitic insects such as fleas a double adjustment is necessary, firstly in response to direct conditions, secondly in relation to the effects of seasonal changes on their hosts' habits. This latter factor must be most important in moulding flea bionomics, as the habits of flea hosts vary from a continual occupancy of lairs by some wild animals, such as bats and carnivora, to a spasmodic appropriation of convenient situations by wandering animals, such as rats. In the case of birds there is a strictly limited seasonal occupation of the old nest for two or three months only. It is also probable that, even when the home of the host is of a permanent character, and more or less in continual occupation, flea increase will be adjusted to the breeding periods of its host; it is unquestionably at these times that the best opportunity occurs for uninterrupted feeding on the part of the adult fleas, and a consequent ample food supply for their larvae.

Nomadic animals which do not possess the homing instinct are far less likely to have specific fleas allotted to them than other animals. With *P. irritans* there seems little need for any adjustment in temperate climes. With *C. fasciatus* the conditions have also become modified, but the primitive habits of this species are less likely to have suffered change than those of *P. irritans*, as only a portion of the rat population is closely enough associated with dwellings for their parasites to enjoy the full benefits of domestic life.

So far as ascertained in the course of these experiments, *C. gallinae* has a very definite breeding season during spring and early summer—the adults emerging in the spring and living through winter. Its habits arc loose in other respects and it appears to have so adjusted itself as to be able to obtain sufficient nourishment for breeding purposes from the blood of its host almost as quickly as *P. irritans*. It is possible that the exigencies of an existence begun in an *empty* nest have forced upon it the necessity of leaving no chance untried of providing for the future of its race.

Breeding when fed on an Alien Host. In view of the fact that the species experimented with, can live for considerable periods when fed on the blood of an alien host the question of their breeding under these circumstances becomes one of considerable interest. Pairing certainly took place but no eggs were developed, so far as could be observed without dissecting specimens, certainly none were laid. This was at first thought to be due to the nature of the food alone, but it subsequently appeared to be connected with the conditions of captivity and the comparatively limited opportunities to feed.

C. gallinae. Among some fleas taken from a dog in November 1910, was a female specimen of *C. gallinae*; this flea was fed on a human host throughout the winter and during March laid a few ova which proved to be infertile. During February 1911 seven specimens of *C. gallinae* were taken from a deserted Tit's nest and were fed on a human host. Copulation was seen to occur among them but most of the males soon died off, the female specimens living longer, and one which survived for 41 days laid some 20 eggs during March. These eggs proved to be fertile, and larvae to the number of 16 were reared without loss, a few being used as specimens, the remainder producing adult fleas.

C. fasciatus. Trials lasting from 4 to 79 days (average 27), were carried out with three batches of fleas, comprising 22 individuals, but no ova were laid. A further experiment with this species, consisting of a batch of 16 fleas boxed with a tuft of rat's hair, was in progress for over a month, but no eggs resulted, although the box was kept in the humid incubator at 75° F. and the fleas were seen to copulate on several occasions. Both *C. gallinae* and *C. fasciatus* will pair before feeding, in fact shortly after emergence.

X. cheopis. Two batches, consisting of 19 and 15 individuals respectively, lived on a human host for from 18 to 104 days (average 63 days), but no eggs were laid.

P. irritans. Two attempts to breed this species when fed on rats failed to produce either eggs or brood. In one case six specimens were put into a cage with a young rat, and one individual lived for 40 days, but no larvae could be found nor did the cage produce any fleas. In a second attempt *P. irritans* was fed on the rat by the box method; the length of life was, however, very short in this case, none of the fleas surviving more than 14 days, and it seems probable that little if any actual feeding was done. No eggs were laid. It is possible that *P. irritans* may breed to a limited extent on the dog as we occasionally rear a few individuals from among the abundant supply of flea larvae in the dog's bed, but it is probable that the ova which give rise to these larvae were laid within a day or so after the fleas were transferred to the dog's coat.

Ct. canis. Three batches consisting of 14 individuals, three of which were captured and the remainder bred, were fed on a human host for varying periods of from 15 to 245 days (average 71 days), but no ova were laid. A fourth batch of 20 specimens—fresh specimens being added from time to time—were boxed with a quantity of the dog's hairs placed in the box, to see if the association had any effect and fed for some months. No eggs were laid, however, although the box was kept in the humid incubator at 75° F. except during feeding times. In this case it can hardly be a question of season, for the same species was breeding successfully in the dog's bed while the experiment was in progress; this was shown by the presence of eggs.

About 60 freshly emerged specimens of *Ct. canis* were put into a cage with a young rat, none of them survived a month and no brood was discoverable, nor did any fleas emerge later in the cage. Ten specimens fed on the rat by the box method lived for varying periods of from 24 to 58 days (average 41 days), but no ova resulted.

Ct. felis. Only one attempt has been made with this species; five individuals comprising both sexes were fed on man for periods varying from 139 to 185 days. No eggs were laid.

Ova were successfully obtained from boxed specimens of *Ct. canis* taken from the dog, and of course ova of both *C. fasciatus* and *X. cheopis*, are freely obtained by the box method when the adult fleas are taken from the rat cages. This tends to suggest that some specific character of the blood ingested is the controlling factor in egg production; it must, however, be noted that when either *C. fasciatus* or *X. cheopis* has been fed by means of the box method on the rat no eggs have resulted. Three attempts were made with *C. fasciatus* fed on a rat by the box method; 24 individuals were used and survived from four to 106 days (average 23 days), yet no eggs were laid. A later attempt with rat's hair in the box has also proved negative; in this case 20 fleas were fed on a rat for some three weeks.

In comparison with *P. irritans,* all the other species observed are in much closer association with their hosts. They probably are accustomed to feed in a much more leisurely manner and at more frequent intervals than the human flea. It was therefore decided to test the effect of more frequent feeding on man, and batches of *X. cheopis, C. fasciatus* and *Ct. canis* were fed twice instead of once a day, the second feeding being of longer duration than the usual 15 minutes.

The experiment proved partially successful; *C. fasciatus* was found to lay eggs freely and a gradually increasing stock of this species has been maintained, apart from any other source of supply. *X. cheopis* laid sparingly, but although fleas were reared from the resulting larvae and added to the adult feeding box, the experiment could not have been continued were it not that individuals reared on the rat were also added to keep up the supply of parents. *C. gallinae* proved a somewhat better layer than *X. cheopis* but stocks could not be long maintained without the addition of adult fleas from other sources.

It is of course quite improbable that *C. fasciatus* could perpetuate its race by adopting a human host, as no proper provision would be available for the larvae. *X. cheopis,* however, is more adaptable in the matter of food and this difficulty would not apply.

No success has, however, attended any attempts with *Ct. canis.* The adults of this species, like those of *X. cheopis,* practically live upon their host, and possibly practise very constant feeding. It may be that the two opportunities per day on an alien host are not sufficient and that very frequent feeding might induce *Ct. canis* to lay eggs when fed on man[1].

The whole of the foregoing evidence is entirely opposed to the view that fleas can continue breeding in the absence of food for the adults.

To account for the records of large numbers of fleas existing in long deserted dwellings, or the unoccupied beds of animals, the explanation has been put forward that in the presence of ample nourishment for the larvae, generations of fleas might be reared in spite of an entire absence of any food supply for the adult fleas. It is assumed that the nutriment absorbed during larval existence suffices for egg production, as well as for the development of sperms in fleas; this is of course the case with many insects.

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[1] Later trials with this species have proved quite successful. When given opportunities of feeding on a human host, which extended to five hours daily, a considerable number of eggs were laid, all of which, however, failed to hatch. The possible feeding period was then increased to at *least twelve* hours per day and eggs were freely laid, a large proportion of which hatched. The resulting larvae were successfully reared and over thirty adult *Ct. canis* emerged from the cocoons spun by these larvae. There seems no obvious reason why dog fleas should require so much longer for feeding than those associated with rats or fowls, but I am inclined to think that the solution of the problem is in some way bound up with the needs of the larvae in the matter of food. The increased number of eggs laid by the twice fed *P. irritans* (see Sect. V., Influence of Food Supply on Fertility) appears to me to favour such a suggestion.

As stated elsewhere in this report, copulation certainly takes place among newly emerged unfed fleas. The habit has been commonly observed in most of the species dealt with and may be universal. Dissection of the larvae, pupae and imagines proves that developing ovaries may be found in the full fed and resting larvae, and onwards through the pupal period in various stages of development. The ova, however, are undersized, even after active imaginal existence has started. Throughout the whole course of these experiments oviposition has always been preceded by several days' feeding, and no single instance was observed in which an egg was laid by an unfed female; all the evidence points to the necessity of feeding the adult for the full development of eggs.

The fertility experiment conducted with adults of *P. irritans* to ascertain if length of feeding time had any result on the percentage of eggs hatching also supports this view; it was found that feeding twice a day resulted in a much larger number of eggs than a single daily meal. The number of opportunities for feeding had, however, no noticeable influence on the proportion of eggs which hatched.

When feeding the different species on man by the box method, a considerable difference was noticed in the character of the faeces deposited on the gauze and sides of the box. *P. irritans*, as was to be expected, fed to the greatest excess, blotching and splashing the sides of the box and gauze cover with semi-fluid dejecta, which were frequently bright red in colour. *Ct. canis* tends to deposit its faeces in little piles one upon the other, suggesting that the dejecta in this case were of a more pasty nature than those of the human flea. *C. gallinae* makes a deposit of neat raised dots, very similar to that of *C. fasciatus*, but the feeding of the latter species, to judge by the deposit, seems to be of a less vigorous character. The faeces of the other species tend to be darker in colour than those of *P. irritans* and I have never seen any trace of the fresh blood appearance in the former. It seems not improbable that this difference is due, not so much to a difference in digestion, as to the speed of feeding. In a few minutes *P. irritans* reaches the stage when it voids old accumulations from the gut, whereas, in the case of the other species, the feeding period expires ere they have been able to obtain anything like a surfeit.

IRRITATION CAUSED BY FLEA BITES. The irritation caused by fleas on the human body is known to vary very widely in case of different persons. My assistant developed a distinct papular rash on his arm after feeding some *C. fasciatus* thereon, although the attacks of *P. irritans* did not in any way incommode him. Personally, the bites of fleas do not cause me any irritation whatever, although I am keenly conscious of their progress over my skin. I continued to feed upon myself the particular batch of *C. fasciatus* which caused the trouble referred to above, until they died some weeks later, but without any signs of a rash appearing. Since then I have fed numbers of individuals of the various species upon the same skin area for months together without inconvenience, and my assistant has also fed many specimens including *C. fasciatus*, for several separate periods of a week or more, while I was absent from home, without any recurrence of the rash.

A similar instance of a rash caused by *C. fasciatus* is mentioned by Chick and Martin (1911) and the question of irritation caused by rat fleas and the reaction to them is discussed briefly by Boycott (1912).

LENGTH OF LIFE. The great range of individual variability presented in the earlier stages of the fleas' existence is maintained as regards the length of the adults' life; of this the experiments give abundant examples. Some individuals die off quite early in the experiment, especially when the host is alien. The majority go steadily on for a time, dropping out gradually in a middle period. A few become thoroughly adjusted to their environment and food and far exceed all their companions in longevity. These very long lived specimens are always, in my experience, females.

SECTION V. EXPERIMENTAL STUDY OF THE INFLUENCE OF EXTERNAL CONDITIONS UPON THE VARIOUS STAGES IN THE LIFE HISTORY.

It will be noticed that in the earlier experiments there is fair continuity between the tables dealing with ova and those concerning the larval period (see ova Tables I, II, III, and V; larvae Tables XVI, XVII, XVIII, XXI, and XXII, up to March 1911). The cases where experiments dealing with ova were not continued through the larval stage are few and the deficiency was owing to the young larvae being required for bacteriological experiments. There are also cases in which larval experiments have no previous record. This is due to the difficulty and great labour involved in determining the exact time and circumstances of the hatching. There is no artificial break in continuity from larval to cocoon stage in this series, but many of the larval records end before the spinning period is reached (see Tables XVI, XX and XXI).

In the experiments subsequent to March 1911, no continuity is attempted from the egg- through the larval- to the cocoon stage, all three are treated separately. The hatching experiments were concluded at the emergence of the young larvae, which were then returned to cages in which reserve stocks were kept. For the rearing experiments only those larvae were used which hatched from eggs laid and kept at 75° F.; they were removed daily and divided into batches for distribution among jars maintained under different experimental conditions. For tests with cocoons, full sized larvae were taken from the breeding cages (or breeding jars in case of *P. irritans*) and placed with food and sand at 75° F. The cocoons were then collected daily in batches and distributed to the experimental jars as in the case of larvae.

1. EGGS.

In the experiments made with ova before the end of January 1911, the method adopted was to place the eggs on paper or cloth in the receptacle in which the larvae were to be reared, the sand and food being added before the eggs were put in. This plan was adopted so as to give the larvae every chance of survival, but it entailed the rather cumbersome process of examining the ova individually to see if they had hatched; the periodic examination of the eggs was also rendered difficult because they were frequently dislodged or dragged off the paper or cloth into the sand, presumably by the larvae in their attempts to get clear of the shell[1].

After the first experiment with newly hatched larvae had revealed their fasting powers the much more convenient plan was adopted of placing each batch of eggs in a clean dry tube and recording the number of larvae removed daily to the receptacle in which they were to be reared. A quantitative examination of the empty shells was also made in a number of cases and the results were found to be in close agreement with the record of larvae transferred. The earlier method may therefore be taken to give correct results of hatching save that the number of eggs remaining on the cloth, etc. was often considerably less than the actual number of ova used and the percentage of fertility is apt to be lowered owing to the fact that fertile eggs are more apt to be dislodged than the infertile.

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[1] The egg shell is ruptured, not eaten through. A long slit on the side of the egg is made through which the larva escapes. This slit appears to give the empty shells very elastic or spring-like qualities, for they will frequently fly at the slightest touch of a camel hair brush.

C. fasciatus. A comparison of moistened with unmoistened conditions (Tables I and II) in the incubators shows, in case of *C. fasciatus*, that moistened conditions are on the whole favourable to hatching of eggs while a slight tendency in the opposite direction is shown in case of incubator 75 Wet. The advantage of humidity is also seen by comparing results of experiments in the incubators in which hatching took place in tubes with those where jars or boxes were used. The proportion of eggs is higher in the former case presumably because the conditions were much more favourable to the retention of moisture. In the experiment made in Incubator 75 Wet the result is, however, doubtful and, in case of hatching in the cellar and laboratory cupboard, the reverse is true. The favourable effect of humid conditions in the general experiments is, as a whole, not very apparent as it is to a considerable extent masked by the wide range of individual variation which appears to apply in some measure to the fertility of eggs as well as the other characters of these insects. When, however, we select a single experiment planned on lines to bring out this point the advantage of humid conditions seems unmistakable.

Experiments with ova of C. fasciatus *in card jars* (*unmoistened*)
Table II.

Date	Incubator	Temperature	Average humidity during progress of experiment	Number hatching
21 Dec. 1910	75 Wet	74·2 F.	·75	28 out of 32 = 87 °/₀
21 Dec. 1910	75 Dry	75·7 F.	·46	14 out of 26 = 54 °/₀
24 Dec. 1910	85 Wet	83·6 F.	·70	16 out of 26 = 62 °/₀
24 Dec. 1910	85 Dry	83·8 F.	·59	9 out of 28 = 32 °/₀

To test the matter further, a series of experiments, dealing with eggs alone, was planned to detect, if possible, the relative effect of temperature and humidity on the number of eggs laid, their fertility and the percentage hatching (see Table IV). A large number of *C. fasciatus* were taken from the cages and put together ("bulked"), they were then counted out into batches, each batch containing 50 to 70 females. The males were put in with the females, but not counted —there would be, however, approximately the same proportion of males in each batch. Each batch was placed in a 1¼″ glass-bottomed box with a strip of cloth arranged to receive the eggs as described—the box being then buried in a jar of sand and placed in incubator, cupboard, cellar, etc. In series I the ova were allowed to hatch in the place in which they had been laid; in series II eight separate boxes containing eggs laid in different situations were all placed to hatch out in incubator 75 Wet, while in series III the experiment was varied by putting the boxes containing the fleas into incubator 75 Wet, bulking the ova laid, and then putting them away in batches of 50 to hatch out in different places (see Table IV). The four batches which were in incubator 75 Wet throughout (first experiment in each series), should give a measure of variability, and it will be seen that this is a wide one, viz. in the four experiments the proportion of eggs hatched varied from 71 to 85 °/₀. The difference between the incubators 85 Dry and 75 Dry, and 85 Wet and 75 Wet, is not so marked as in the contrasted experiment referred to above under date of December 1910; this is most probably attributable to the fact that the humidity of incubator 85 Dry and 75 Dry, though still considerably lower than in 85 Wet and 75 Wet, was higher in July 1911 than in December 1910; being, for 85 Dry, ·66 in July 1911, as against ·59 in December 1910, and for 75 Dry, ·55 as against ·46. Although the effects of temperature and humidity are clearly apparent, apart from individual variability, some of the finer points that it was hoped to throw light upon are more or less submerged, or reduced to the value of possible tendencies. The results of the three series of experiments set out in Table IV may be summarized as follows, using incubator 75 Wet as a standard:

The conditions in 85 Wet are detrimental to hatching but favourable to the fertility of the eggs laid.

The conditions in 75 Dry are detrimental to hatching but favour the fertility of the eggs laid.

The conditions in 85 Dry are detrimental to hatching and perhaps to the fertility of the eggs laid as well.

The conditions in cellar are favourable to hatching but detrimental to the fertility of the eggs laid.

The conditions in warm cupboard are detrimental to hatching but favour the fertility of the eggs laid.

The conditions in laboratory cupboard are detrimental to hatching but favour the fertility of the eggs laid.

The conditions in beehive are detrimental to hatching but favour the fertility of the eggs laid.

With regard to the suggestion above, that low humidity is favourable to the fertility of the eggs laid under these conditions it must be admitted that the facts are equally well explained on the assumption that the fertility is in inverse ratio to the number of eggs laid. High temperature when combined with a fair to high humidity is especially favourable to egg laying. It will be observed that in incubators 85 Dry and 85 Wet, which were on the whole not favourable to the fertility of the eggs laid in them, the number of eggs laid per female was usually greater than in those places which appear more favourable to fertility.

P. irritans. A similar experiment was planned (Table VI) on lines as nearly as possible to the foregoing one with *C. fasciatus.*

20 females, after feeding for one week, were divided into four batches and placed in boxes with a number of males which had been treated similarly. The batches A, B, C and D were fed daily for 15 to 20 minutes and kept for the rest of the day in sand pots placed in incubators 75 Wet, 75 Dry, 85 Dry, and the cellar respectively; eggs were removed from the boxes every three or four days. The females of each batch A, B, C and D were unchanged throughout and those that died were not replaced. The males, however, were replaced as they died and their numbers were increased from three to 10 in each box, but this increase was always made at the same time from a single batch that had emerged within a few days of each other, so as to preserve similar conditions for each batch, the object being to vary temperature and humidity only.

After the batches had been kept under the original set of conditions for some two or three weeks they were submitted to fresh ones and after a further period returned to their original situations. In the first two experiments of each batch the ova were allowed to hatch in the situation in which they had been laid, later they were all put into incubator 75 Wet to hatch in order that the effect of varied conditions on their fertility might be tested. Batch A started in incubator 75 Wet, was transferred to 85 Dry and returned to 75 Wet. Batch B started in incubator 75 Dry, was transferred to the cellar and returned to 75 Dry. Batch C started in incubator 85 Dry, was transferred to 75 Wet and returned to 85 Dry. Batch D started in the cellar, was transferred to incubator 75 Dry and returned to the cellar. Finally (see Table VI (*a*)) all the different batches of fleas A, B, C and D were kept under similar conditions, the eggs laid were "bulked," divided into batches and put away in different places to hatch.

The experiment shows that hot dry conditions were most favourable to oviposition, the results being as follows:—the adults in incubator 85 Dry (temperature 83·9° F., humidity ·61) showed 1·54 eggs per female per day: incubator 75 Dry (temperature 74·6° F., humidity ·60) 1·40: incubator 75 Wet (temperature 75° F., humidity ·77) 1·11 and cellar (temperature 63° F. max., 62° F. min., humidity ·94) ·70 eggs per female per day.

The effect of transference from the coolest conditions to a higher temperature and drier atmosphere (batch D) was to increase egg laying, and for reverse conditions (batch B) to decrease it—both changes having a progressive effect; that is to say, in both cases the increase or decrease was more marked in the second period of time than the first. On the other hand, change from the moderate conditions of heat and moisture in incubator 75 Wet (batch A) to the hotter and drier incubator, 85 Dry, tended at first to check but subsequently to increase egg laying, while the reverse change (batch C) caused a progressive rise beyond an already high percentage. The return of the boxes to their original situations produced a rise with batch A, a reduction with batch C, a marked increase with batch B and an equally noticeable drop for batch D.

The final transfer of the batches to incubator 75 Wet produced an increase in the number of eggs laid in case of batches B and C, presumably in response to the more humid conditions; a marked rise in batch D was also to be expected. In case of batch A which had remained in incubator 75 Wet for two successive periods the number fell in the second. This may have been an oscillation in the reverse direction after its spurt following upon the previous change, or, more probably, in response to the falling humidity in incubator 75 Wet itself.

Individual variation is not so apparent in this experiment as it was in that dealing with *C. fasciatus*. This was to be expected in view of the fact that we are here dealing with only 20 females of *P. irritans*, whereas with *C. fasciatus* hundreds were taken from the cages on several different occasions.

The influence of temperature and humidity upon fertility, apart from the percentage hatching, is shown by a comparison of the percentage of eggs hatching in incubator 75 Wet after being laid under other conditions and may be studied from Table VI (*b*) of which the details have been collected from various experiments in Table VI. For instance, the eggs of batch B when laid in incubator 75 Dry show a higher percentage hatching in incubator 75 Wet (58 %, Table VI (*b*)) than in incubator 75 Dry (44 %, Table VI); when the ova of this batch were laid in incubator 75 Wet and placed in incubator 75 Dry to hatch, the proportion hatching was lower still. In these figures, other things being equal, we have evidence that the conditions in incubator

75 Dry are favourable for fertility of the eggs laid there, as shown by the increased proportion hatching when moved to suitable conditions for this second stage.

In Table VI (*a*) are given the results of a special experiment to determine the best conditions for hatching, all the eggs used being laid in incubator 75 Wet and placed in different places to hatch out. From the results it seems clear that the conditions of heat and drought in incubator 93 Dry are detrimental to hatching[1], and this is also the case in incubator 75 Dry, which is still drier but not so hot; the cellar, on the other hand, while detrimental to fertility (see Table VI (*b*)) is favourable to hatching.

The experiments with *P. irritans* do not lend any support to the suggestion mentioned in case of *C. fasciatus,* viz. that fertility might bear some relation to egg production, being in inverse ratio to the number of eggs laid. That is to say that, under the forcing conditions of high temperature, immature eggs are deposited. With *P. irritans* it would rather seem that the high temperature induced not only free laying, but increased facility for sperms to come in contact with the eggs.

The suggestions to be gained from the above experiments as regards hatching and fertility of eggs are the following

P. irritans. *Incubator 75 Wet as Standard.*

The conditions in incubator 85 Dry favour fertility and are detrimental to hatching.
The conditions in incubator 75 Dry favour fertility and are detrimental to hatching.
The conditions in the cellar are detrimental to fertility but favourable to hatching.

X. Cheopis. Considerable difficulty was experienced in getting sufficient stock to carry out egg experiments with this species on as full a scale as with *C. fasciatus.* The rapid breeding that took place during the summer of 1911 led to an expectation of a liberal supply in the autumn and winter, but experience proved that the numbers dwindled rapidly when the hot weather had passed and the effects of renewed breeding were not apparent in the cages until late spring and early summer of 1912. There is no doubt that this species requires an average temperature of from 65 F. to 70 F. for rapid increase, and, quite apart from the question of seasonal habit, the temperature in the laboratory, where the cages were kept, fell so low during the night as to check breeding except during really warm summer weather.

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[1] The continuity of this experiment with the one detailed in Table VI has been somewhat impaired by a rise in the temperature of incubator 85 Dry from 85° F. to 93° F. in order to carry out the experiments dealing with *X. cheopis.*

The methods followed for the study of external conditions upon fertility and hatching of eggs were the same as those adopted with *C. fasciatus*, which have already been described; the results are set forth in Tables VII and VIII.

From a study of the earlier experiments (see Table VII) performed during July and November 1911 and January 1912, it will be noticed that either a seasonal change takes place with regard to the fertility of the ova (*i.e.* eggs are less fertile when laid out of season), or else the reduction in humidity, which is of general occurrence in the incubators during the autumn, has a detrimental effect on their hatching. Whatever be the cause it is patent that cool conditions, such as are presented by the laboratory cupboard, cellar and beehive during autumn, winter and spring, are fatal to *all* the eggs subjected to them. The falling off in the percentage of eggs hatching of both *P. irritans* and *C. fasciatus* that are placed at temperatures in the neighbourhood of 55 F. or lower is also very marked (see *C. fasciatus* Table IV, cellar 20th April 1911, and *P. irritans* Table VI), although there is no case of the complete failure of all the eggs in any one batch.

The results of the threefold test with *X. cheopis* (Table VIII) are disappointing in view of the small number of eggs deposited, and show to an even greater extent than *C. fasciatus* the variability as regards the percentage of eggs hatching in incubator 75 Wet on different dates. This difference must be taken into account, nor can we draw any safe conclusions as to the effects of the varied conditions to which the eggs were subjected, unless the trials took place on identical dates. Under these conditions, as the eggs used were all portions of a single batch or all laid by detachments of one body of females, the difference may be taken to represent the effect of the varied condition alone.

The results, summed up in a brief table of conclusions, as in the case of *P. irritans* and *C. fasciatus*, may be stated as follows:

Incubator 75 Wet as Standard.

The conditions in incubator 93 Wet are unfavourable but not necessarily fatal to both fertility and hatching.

The conditions in incubator 75 Dry are on the whole somewhat less favourable to both fertility and hatching than 75 Wet but any change from one to the other is distinctly unfavourable.

The conditions in incubator 93 Dry are certainly very unfavourable, probably fatal, to hatching, but as regards the fertility of the ova laid are not unfavourable, about *parallel* with 75 Dry.

The conditions in cellar are very detrimental to egg laying and unfavourable to hatching; the effect on fertility is questionable.

The conditions in warm cupboard are somewhat unfavourable for hatching but not to the fertility of eggs laid.

The conditions in laboratory cupboard are distinctly unfavourable for laying, hatching and perhaps fertility as well.

The conditions in beehive are distinctly unfavourable for laying, hatching and perhaps fertility as well.

The conditions in ice-chest are fatal.

The evidence for these conclusions is admittedly even less decisive than it was for the tabulated conclusions in regard to the other species. They must be viewed in the light of suggestions and in no way final.

TABLE I. *Ova* C. fasciatus. *Influence of temperature and moisture on the proportion hatching; all eggs laid in incubator "75 Wet."*

(*a*) Incubator 75 Wet, moistened.

Date	Receptacle Tube	 Box	 Jar	Temperature	Moistened	Number examined	Number hatched	Per-centage
1 Dec. 1910	×			74·0	Water at start	11	11	100 %
6 Dec. 1910	×			74·1	Water at start	21	18	85 %
8 Dec. 1910	×			74·3	Water at start	14	14	100 %
*28 Dec. 1910			×	74·6	Water at intervals	29	21	73 %
13 Jan. 1911	×			74·7	Water at start	16	13	81 %
* 4 Mar. 1911			×	74·6	Water 1 c.c. daily	36	13	36 %
Total hatched	90 %		53 %					
*28 Dec. 1910			×	74·6	Urine at intervals	30	23	77 %
* 4 Mar. 1911			×	74·6	Urine 1 c.c. daily	36	25	69 %
Total hatched			73 %					
				(*b*) Incubator 75 Dry, moistened.				
8 Dec. 1910	×			74·7	Water at start	19	12	63 %
17 Dec. 1910	×			76·2	Water at start	25	21	84 %
* 3 Jan. 1911			×	76·1	Water at intervals	21	13	62 %
*31 Jan. 1911			×	76·6	Water daily	27	20	74 %
28 Feb. 1911			×	76·0	Water 1 c.c. daily	30	17	57 %
Total hatched	75 %		64 %					
* 3 Jan. 1911			×	76·1	Urine at intervals	19	12	63 %
*31 Jan. 1911			×	76·6	Urine daily	39	21	54 %
28 Feb. 1911			×	76·0	Urine 1 c.c. daily	30	15	50 %
Total hatched			55 %					
				(*c*) Incubator 85 Wet, moistened.				
1 Dec. 1910	×			83·5	Water at start	17	11	65 %
8 Dec. 1910	×			83·8	Water at start	8	7	88 %
*30 Dec. 1910			×	84·2	Water at intervals	20	16	80 %
*24 Feb. 1911			×	83·7	Water 1 c.c. daily	36	21	58 %
Total hatched	72 %		66 %					
*30 Dec. 1910			×	84·2	Urine at intervals	27	24	88 %
*24 Feb. 1911			×	83·7	Urine 1 c.c. daily	36	19	53 %
Total hatched			68 %					

* against experiments of the same date signifies that a single batch of eggs was divided.

(*d*) Incubator 85 Dry, moistened.

Date	Receptacle			Temperature	Moistened	Number examined	Number hatched	Percentage
	Tube	Box	Jar					
*25 Nov. 1910			×	84·1	Water at intervals	15	8	53 %
1 Dec. 1910	×			83·8	Water at start	18	11	61 %
6 Dec. 1910	×			84·0	Water at start	20	18	90 %
8 Dec. 1910	×			84·0	Water at start	17	11	65 %
17 Dec. 1910	×			84·7	Water at start	24	19	79 %
*30 Dec. 1910			×	83·6	Water at intervals	17	15	88 %
*27 Jan. 1911			×	85·1	Water daily	16	9	56 %
Total hatched	75 %		66 %					
*25 Nov. 1910			×	84·1	Urine at intervals	18	13	88 %
*30 Dec. 1910			×	83·6	Urine at intervals	23	21	91 %
*27 Jan. 1911			×	85·1	Urine daily	10	4	40 %
Total hatched			75 %					

(*e*) Warm Cupboard, moistened.

* 3 Feb. 1911			×	59·0	Water daily	25	19	76 %
* 8 Mar. 1911			×	60·0	Water 1 c.c. daily	35	16	48 %
Total hatched			58 %					
* 3 Feb. 1911			×	59·0	Urine daily	19	12	62 %
* 8 Mar. 1911			×	60·0	Urine 1 c.c. daily	35	12	34 %
Total hatched			42 %					

TABLE II. *Ova* C. fasciatus. *Influence of temperature and humidity on proportion of eggs hatching; all eggs laid in incubator* "75 *Wet.*"

(*a*) Incubator 75 Wet, unmoistened.

Date	Receptacle			Temperature	Humidity	Number examined	Number hatched	Percentage
	Tube	Box	Jar					
5 Aug. 1910	×			75	·66	5	4	80 %
11 Aug. 1910		×		75	·69	10	6	60 %
24 Sept. 1910			×	74	·73	20	16	80 %
30 Sept. 1910		×		74·1	·77	7	5	71 %
16 Oct. 1910	×			74	·73	15	15	100 %
19 Oct. 1910		×		74	·66	11	9	82 %
30 Oct. 1910	×			73·7	·72	6 13	6 13	100 % 100 %
21 Dec. 1910			×	74·2	·75	32	28	87 %
13 Jan. 1911	×			74·7	·74	17	14	82 %
14 Feb. 1911	×			74·5	·76	14	10	71 %
14 Feb. 1911	×			74·5	·76	19	12	63 %
14 Feb. 1911	×			74·5	·76	18	12	67 %
Total hatched	80 %	72 %	85 %					

* against experiments of the same date signifies that a single batch of eggs was divided.

Date	Receptacle			Temperature		Humidity	Number examined	Number hatched	Percentage
	Tube	Box	Jar	Max.	Min.	Approximate			
				(*b*) Cellar.					
31 July 1910	×			59	58	·93	2	1	50 %
4 Aug. 1910	×			59	58	·93	5	4	80 %
14 Aug. 1910	×			62	60	·93	3	1	33 %
7 Oct. 1910			×	58	57	·93	22	19	86 %
22 Oct. 1910	×			56	55	·93	7	3	43 %
Total hatched	53 %		86 %						
				(*c*) Incubator 85 Dry, unmoistened.					
24 Dec. 1910			×	83·8		·59	28	9	32 %
				(*d*) Incubator 85 Wet.					
30 July 1910	×			85		·75	7	4	57 %
4 Aug. 1910	×			85		·74	6	4	66 %
10 Aug. 1910		×		85		·73	11	1	9 %
9 Sept. 1910		×		85		·70	5	3	60 %
22 Sept. 1910			×	85		·72	20	12	60 %
13 Oct. 1910	×			84·5		·72	11	9	82 %
5 Nov. 1910	×			84·7		·72	15	14	93 %
24 Dec. 1910			×	83·6		·70	26	16	62 %
Total hatched	74 %	25 %	61 %						
				(*e*) Incubator 75 Dry.					
21 Dec. 1910			×	75·7		·46	26	14	54 %
				(*f*) Warm Cupboard.					
				Max.	Min.	About			
6 Aug. 1910	×			69	67	·60	3	3	100 %
10 Oct. 1910			×	74	69	·60	16	10	61 %
22 Oct. 1910	×			73	69	·60	6	5	83 %
				(*g*) Laboratory Cupboard, unmoistened.					
				Of Laboratory Approximate only		Approximate			
25 July 1910	×			60		·84	3	3	100 %
6 Aug. 1910		×		60		·84	5	2	40 %
12 Aug. 1910		×		60		·84	6	4	66 %
18 Aug. 1910	×			60		·84	6	3	50 %
27 Sept. 1910			×	60		·84	9	6	66 %
16 Oct. 1910		×		60		·84	16	15	94 %
19 Oct. 1910		×		60		·84	8	5	63 %
Total hatched	66 %	80 %	66 %						

TABLE III. *Ova* C. fasciatus. *Influence of varying the temperature and humidity upon the proportion of eggs of the same batch hatching; all eggs laid in incubator "75 Wet."*

Date 1910	Receptacle	Place	Temperature		Humidity	No. exam.	No. hatched	Per-centage
			Unmoistened.					
19 Oct.	Box	Incubator 75 Wet	74		·66	11	9	82 %
		Lab. Cupboard	60 approx.		·84 approx.	8	7	87 %
			Max.	Min.				
22 Oct.	Tube	Warm Cupboard	73	69	·60	6	5	83 %
		Cellar	56	55	·90	7	3	43 %
			Moistened.					
1 Dec.	Tube	Incubator 85 Wet	83·5		Water at start	17	11	65 %
		,, 85 Dry	83·8		,, ,,	18	11	61 %
6 Dec.	Tube	,, 75 Wet	74·1		,, ,,	21	18	85 %
		,, 85 Dry	84·0		,, ,,	20	18	90 %
8 Dec.	Tube	,, 75 Dry	74·7		,, ,,	19	12	63 %
		,, 85 Dry	84·0		,, ,,	17	11	65 %

NOTE. Moistened by means of a disk of blotting-paper beneath the sand with a projecting tag.

TABLE IV. *Experiment with Ova* C. fasciatus. *The relative effect of varied conditions of Temperature and Humidity on (a) Fertility of eggs laid, (b) Hatching of eggs laid.*

	Series I Females put in different places to lay and ova allowed to hatch in the same places as laid							Series II Females put into different places to lay. Ova hatched in Incubator 75 Wet						Series III Females all put into Incubator 75 Wet to lay. Ova distributed in batches into the different places to hatch				
			Laid and hatched						Hatched						Hatched			
Place	Number of females used	Date, 1911	Tempera-ture	Humidity	No. of eggs laid	Percentage per female	Number hatched	Date, 1911	Tempera-ture	Humidity	No. of eggs laid	Percentage per female	Number Hatched	Date, 1911	Tempera-ture	Humidity	No. of eggs	Number Hatched
Incubator 75 Wet	50	11 April	75·3	·77	54	1·08	45 = 85 %	7 July	76·7	·88	60	1·20	44 = 73 %	18 July	76·3	·81	50	41 = 82 %
	50	20 July	76·4	·82	89	1·78	63 = 71 %											
Incubator 85 Wet	50	11 April	84·6	·71	65	1·30	43 = 66 %	30 May	75·9	·90	78	1·56	54 = 69 %	20 July	85·8	·83	50	33 = 66 %
	50	20 July	85·8	·83	97	1·94	43 = 44 %											
Incubator 75 Dry	50	20 April	75·5	·48	37	·74	26 = 70 %	30 May	75·9	·90	41	·82	35 = 87 %	19 July	76·6	·55	50	31 = 62 %
	50	20 July	77·1	·56	51	1·01	38 = 75 %											
Incubator 85 Dry	50	20 April	83·9	·64	82	1·64	42 = 51 %	30 May	75·9	·90	42	·84	21 = 50 %	20 July	84·1	·66	50	27 = 56 %
	50	20 July	84·1	·66	85	1·70	36 = 42 %											
Cellar	50	20 April	max. min. 51·7 50·1	·90	11	·22	3 = 27 %	7 July	76·7	·88	58	1·16	46 = 79 %	18 July	max. min. 62·9 61·8	·94	50	47 = 94 %
	50	24 July	65·6 64·4	·94	11	·22	9 = 82 %											
Warm cupboard	70	11 April	65·7	·53	23	·33	4 = 17 %	7 July	76·7	·88	21	·42	14 = 67 %	18 July	72·1	·62	50	28 = 56 %
	50	24 July	73·8	·62	3	·06	1 = 33 %											
Laboratory cupboard	60	11 April	max. min. 59·2 47·3	·76	8	·13	2 = 25 %	7 July	76·7	·88	43	·82	37 = 86 %	18 July	max. min. 72·6 64·9	·72	50	31 = 62 %
	50	24 July	74·2 65·7	·73	18	·36	15 = 83 %											
Beehive	50	20 April	67·0 34·6	—	20	·40	9 = 45 %	7 July	76·7	·88	48	·96	37 = 77 %	18 July	82·2 57·8	—	50	20 = 40 %
	50	25 July	82·1 69·2	—	6	·12	4 = 67 %											

Table V. *Ova* P. irritans. *Influence of the temperature and humidity upon hatching of eggs; all eggs laid in incubator "75 Wet."*

Date	Tube	Box	Jar	Temperature	Humidity	No. examined	No. hatched	Percentage hatched
				Incubator 75 Wet.				
1 Oct. 1910	×	—	—	74·1	·79	8	8	100 %
10 ,,	—	—	×	74·2	·78	49	45	92 %
10 ,,	×	—	—	74·2	·78	12	7	58 %
*14 ,,	—	×	—	74·2	·75	23	15	65 %
15 Feb. 1911	×	—	—	74·5	·76	23	17	74 %
15 ,,	×	—	—	74·5	·76	23	12	52 %
				Incubator 85 Wet.				
26 Sept. 1910	—	—	×	85	·74	27	23	85 %
14 Oct. 1910	—	×	—	84	·72	16	11	69 %
				Cellar.				
				Max. Min.				
6 Oct. 1910	—	—	×	58 57	·90 approx.	21	9	43 %
*14 ,,	—	×	—	56 55	·90 ,,	18	11	61 %
				Laboratory Cupboard.				
11 Aug. 1910	×	—	—	about 60	·83 approx.	12	9	75 %
1 Oct. 1910	—	—	×	,, 60	·85 ,,	31	24	77 %
				Warm Cupboard.				
				Max. Min.				
22 Sept. 1910	×	—	—	76 69	·60 approx.	8	3	37 %
18 Oct. 1910	—	×	—	73 69	·60 ,,	12	4	33 %

* Signifies a portion of a divided batch of eggs.

TABLE VI. *Ova* P. irritans. *Twenty females, fed for one week, were divided into four batches and kept in boxes with a number of males. These batches were then subjected to varied treatment as regards Temperature and Humidity.*

Dates	Batch	Number of females	Number of males	Place where fleas were kept	Temperature	Humidity	Number of eggs laid per female per day	Number laid	Hatched	Place where eggs were kept till hatched
18 Aug.—1 Sept.	A	5	Av. 4·7	Incubator 75 Wet	75	·77	1·11	86	42 = 51 %	Incubator 75 Wet
2—18 Sept.	A	Av. 4·4	6	,, 85 Dry	84·3	·58	1·00	74	Nil	,, 85 Dry
19 Sept.—9 Oct.	A	4	6	,, 85 Dry	84·8	·58	1·21	102	36 = 35 %	,, 75 Wet
10 Oct.—1 Nov.	A	3	Av. 8·8	,, 75 Wet	74·3	·74	1·55	107	53 = 49 %	,, 75 Wet
2 Nov.—25 Nov.	A	3	Av. 9·1	,, 75 Wet	74·6	·70	1·18	85	35 = 41 %	,, 75 Wet
18 Aug.—1 Sept.	B	5	Av. 5	Incubator 75 Dry	74·6	·60	1·40	110	48 = 44 %	Incubator 75 Dry
2—18 Sept.	B	5	6	Cellar	max. min. 62 61	·94	1·03	93	25 = 27 %	Cellar
19 Sept.—9 Oct.	B	5	6	Cellar	57 56	·93	·43	45	9 = 20 %	Incubator 75 Wet
10 Oct.—1 Nov.	B	5	Av. 9·1	Incubator 75 Dry	74·3	·53	1·61	185	108 = 58 %	,, 75 Wet
2 Nov.—25 Nov.	B	4·1	Av. 8	,, 75 Wet	74·6	·70	1·71	171	87 = 50 %	,, 75 Wet
18 Aug.—1 Sept.	C	5	Av. 4·7	Incubator 85 Dry	83·9	·61	1·54	116	22 = 19 %	Incubator 85 Dry
2—18 Sept.	C	Av. 4·2	Av. 5·6	,, 75 Wet	75·1	·77	1·58	106	49 = 46 %	,, 75 Wet
19 Sept.—9 Oct.	C	4	6	,, 75 Wet	74·2	·74	1·84	155	66 = 42 %	,, 75 Wet
10 Oct.—1 Nov.	C	Av. 3·8	Av. 9·1	,, 85 Dry	84·5	·61	1·54	135	48 = 35 %	,, 75 Wet
2 Nov.—25 Nov.	C	3	Av. 9·1	,, 75 Wet	74·6	·70	1·9	137	49 = 36 %	,, 75 Wet
18 Aug.—1 Sept.	D	5	Av. 5	Cellar	max. min. 63 62	·94	·70	53	25 = 47 %	Cellar
2—18 Sept.	D	5	Av. 5·8	Incubator 75 Dry	75·1	·56	1·00	90	20 = 22 %	Incubator 75 Dry
19 Sept.—9 Oct.	D	5	6	,, 75 Dry	74·8	·51	1·19	125	55 = 44 %	,, 75 Wet
10 Oct.—1 Nov.	D	5	Av. 9·3	Cellar	max. min. 56 55	·93	·27	31	4 = 13 %	,, 75 Wet
2 Nov.—25 Nov.	D	Av. 4·6	Av. 9·6	Incubator 75 Wet	74·6	·70	·98	110	64 = 58 %	,, 75 Wet

TABLE VI (*a*). *Ova* P. irritans. *Second portion of test. All batches of fleas A, B, C and D kept in Incubator 75 Wet. The ova laid by the several batches were "bulked," then divided into four lots and put under different conditions to hatch.*

Place	Period of laying	Temperature	Humidity	Number of eggs	Number which hatched	Percentage which hatched	Aver.
Incubator 93 Dry	26 Nov.—13 Dec.	93·1	·56	81	9	11 %	9 %
	14 Dec.—3 Jan.	92·9	·57	57	6	10 %	
	4 Jan.—16 Jan.	93·0	·55	33	2	6 %	
Incubator 75 Dry	26 Nov.—13 Dec.	74·7	·49	81	Nil	—	4 %
	14 Dec.—3 Jan.	74·8	·51	57	Nil	—	
	4 Jan.—16 Jan.	74·4	·53	33	7	21 %*	
Incubator 75 Wet	26 Nov.—13 Dec.	76·0	·66	81	36	45 %	52 %
	14 Dec.—3 Jan.	76·1	·66	57	35	61 %	
	4 Jan.—16 Jan.	75·2	·74	33	18	54 %	
		max. min.					
Cellar	26 Nov.—13 Dec.	47·6 45·8	·91	81	20	24 %	26 %
	14 Dec.—3 Jan.	49·4 48·3	·93	57	18	32 %	
	4 Jan.—16 Jan.	48·6 47·4	·93	33	6	18 %	

* Owing to an alteration in Incubator the humidity rose to ·66 for a period of 12 to 20 hours on the 5th Jan. and 4 eggs hatched out of a batch put in on the 3rd Jan. Of subsequent batches 3 eggs hatched with the humidity about ·54 to ·55 for the critical period; the last batch put in on *a falling* humidity failed to hatch.

TABLE VI (*b*). *Ova* P. irritans. *Egg Fertility test (compiled from Table VI). Females put under different conditions to lay eggs; all hatched in incubator* 75 *Wet.*

Batch	Place of laying	Conditions of laying: Temperature ° F.	Conditions of laying: Humidlty	No. of eggs per female laid per day	Conditions of hatching: Temperature ° F.	Conditions of hatching: Humidity	Percentage hatched
A	Incubator 75 Wet	74·3	·74	1·55	74·3	·74	49
B	,, 75 Dry	74·3	·53	1·61	74·3	·74	58
C	,, 85 Dry	84·5	·61	1·54	74·3	·74	35
D	Cellar	55·5	·93	·27	74·3	·74	13

TABLE VII. *Ova* X. cheopis. *Influence of temperature and humidity upon the hatching of eggs; all eggs laid in incubator* 75 *Wet.*

Date	Place of hatching	Temperature ° F.		Humidity	Number of eggs	Number hatched	Percentage
31 July 1911	Incubator 85 Wet	84·6		·81	25	15	60 %
1 Nov. 1911	,,	84·6		·74	21	11	52 %
26 Nov. 1911	,,	3 days at 76 4 ,, 92·5		·65 ·67	24	11	46 %
3 Jan. 1912	Incubator 93 Wet	92·6		·66	13	1	8 %
12 Oct. 1911	,, 85 Dry	85		·61	18	1	6 %
26 Nov. 1911	,, 93 Dry	93·4		·56	24	3	12 %
3 Jan. 1912	,, 93 Dry	93·2		·56	13	3	23 %
31 July 1911	Incubator 75 Wet	75·6		·84	25	19	76 %
12 Oct. 1911	,,	74·7		·76	18	12	66 %
1 Nov. 1911	,,	74·8		·70	24	14	58 %
3 Jan. 1912	,,	75·5		·71	13	5	38 %
31 July 1911	Incubator 75 Dry	76		·60	25	12	48 %
12 Oct. 1911	,,	75		·54	18	3	16 %
26 Nov. 1911	,,	74·8		·49	24	Nil	—
3 Jan. 1912	,,	75·2		·50	13	2	15 %
19 Oct. 1911	Warm Cupboard	70		·56	18	3	16 %
26 Nov. 1911	,,	61		·58	24	Nil	—
		Max.	Min.				
31 July 1911	Cellar	64	63	·94	25	17	68 %
19 Oct. 1911	,,	57	55	·93	18	Nil	—
26 Nov. 1911	,,	48	46	·93	24	Nil	—
19 Oct. 1911	Beehive	60	42	—	18	Nil	—
26 Nov. 1911	,,	45	34	—	24	Nil	—
26 Nov. 1911	Lab. Cupboard	53	45	·87	24	Nil	—

TABLE VIII. *Ova* X. cheopis. *The relative effect of Temperature and Humidity on (a) Fertility of eggs laid, (b) Hatching of eggs laid.*

	Series I							Series II						Series III				
	Females put in different places to lay and ova allowed to hatch in the same places as laid							Females put into different places to lay. Ova all put into Incubator 75 Wet and allowed to hatch						Females all put into Incubator 75 Wet to lay. Ova distributed in batches among the different test places				
			Laid and hatched						Hatched						Hatched			
Place	Number of females used	Date, 1912	Tempera-ture	Humidity	No. of eggs laid	Percentage per female	Number hatched	Date, 1912	Tempera-ture	Humidity	No. of eggs laid	Percentage per female	Number hatched	Date, 1912	Tempera-ture	Humidity	No. of eggs	Number hatched
Incubator 75 Wet	50	15 June	75·3	·83	15	·30	5=33 %	29 July	74·2	·82	38	·76	15=39 %	25 June	75·0	·86	10	5=50 %
	50	2 July	75·3	·80	12	·24	7=58 %							9 Aug.	75·0	·81	18	15=83 %
Incubator 93 Wet	50	15 June	94·0	·81	17	·34	none	29 July	74·2	·82	23	·46	6=26 %	25 June	95·9	·70	10	nil
	50	2 July	95·4	·74	2	·04	none							9 Aug.	93·4	·78	18	5=27 %
Incubator 75 Dry	50	15 June	75·9	·61	12	·24	6=50 %	29 July	74·2	·82	19	·38	4=21 %	25 June	76·0	·59	10	3=30 %
	50	2 July	76·0	·59	16	·32	9=56 %							9 Aug.	75·0	·57	18	6=33 %
Incubator 93 Dry	50	15 June	93·0	·57	17	·34	none	29 July	74·2	·82	30	·60	7=23 %	25 June	93·0	·55	10	nil
	50	2 July	93·0	·54	1	·02	none							9 Aug.	93·0	·54	18	nil
			max. min.												max. min.			
Cellar	50	15 June	57·6 56·5	·93	12	·24	3=25 %	29 July	74·2	·82	1	·02	none	25 June	58·0 57·2	·93	10	nil
	50	2 July	58·5 57·7	·93	none	0	none							9 Aug.	57·5 56·5	·93	18	5=27 %
Warm Cupboard	50	15 June	66·5	·71	6	·12	1=16 %	29 July	74·2	·82	21	·42	9=42 %	25 June	66·7	·69	10	2=20 %
	50	2 July	64·8	·76	22	·44	5=22 %							9 Aug.	64·6	·69	18	9=50 %
Laboratory Cupboard			max. min.												max. min.			
														25 June	64·3 59·6	·80	10	nil
	50	2 July	67·3 61·0	·81	5	·10	none	29 July	74·2	·82	3	·6	none	9 Aug.	63·4 56·3	·83	18	8=43 %
Beehive	50	15 June	70·4 52·3	—	8	·16	2=25 %	29 July	74·2	·82	14	·28	2=14 %	25 June	66·8 52·4	—	10	nil
														9 Aug.	64·2 43·0	—	18	4=22 %
Ice chest	20	15 June	41·9	·98	none	0	none							25 June	41·7	·95	10	nil

TABLE IX. *Ova* Ct. canis. *A number of fleas found in the dog's bed. These were placed in a box and put into Incubator 75 Wet. The eggs were divided and batches put into the different Incubators and Cupboards to hatch.*

Date	Place	Temperature		Humidity	Number of eggs	Number hatched	Percentage hatched
26 July 1911	Incubator 85 Wet	85·3		·82	10	7	70 °/o
,,	,, 75 Wet	76·2		·83	10	8	80 °/o
,,	,, 75 Dry	76·3		·60	10	5	50 °/o
		Max.	Min.				
,,	Cellar	64·5	63·4	·94	10	8	80 °/o
,,	Lab. Cupboard	73·0	65·0	·74	10	7	70 °/o
18 Sept. 1911	Incubator 75 Wet	74·6		·76	17	11	64 °/o

2. LARVAE.

(i) *Ability of newly hatched larvae to exist without food in case.* In Buckland's *Curiosities of Natural History* (Appendix to Fourth Series) a paper on "Fleas," read by the Rev. J. Hussey before the Ashmolean Society of Oxford in 1836, is given as the authority for the statement that young larvae can exist for from two to three weeks without food.

The following experiments have been carried out to test this point:

METHOD. A number of newly hatched larvae were put away in small tubes with three or four scraps of blotting-paper to afford foothold and cover. Coloured blotting-paper is to be preferred, as it shows up the larvae and renders counting easier. In most of the experiments the tubes were corked, but, in order to test if this made any serious difference to the results, a few tests were made with cotton-wool plugs in place of corks and sand in place of the blotting-paper. Any dead larvae were removed daily to avoid all possibility of the survivors feeding on them. (See Tables X, XI and XII.)

While the results obtained support the correctness of Hussey's statement, the differing conditions of temperature and humidity were also found to have a very marked influence. So different were the results with *C. fasciatus* in mid-winter and *P. irritans* in the spring, that a number of repetitions of the experiment were made in order to test how far the difference was specific and how far a question of season. It appears that *C. fasciatus* is much better adapted to survive unfed than *P. irritans*; in one instance, in the cellar, in the winter the average length of life of a batch of larvae without food was 75 days and some individuals survived over 100 days. (See Table X.) There is an apparent well-marked seasonal change in the powers of endurance of *C. fasciatus*, as shown by a comparison of the average length of life in the incubators during winter and summer. This apparent lack of endurance of summer hatched larvae is really more marked than at first sight appears, if we consider the fact that the humidity in the incubators is higher in the summer than in the winter[1]. Judging, however, by the fact that this seasonable difference is confined to the experiments with incubators and is not traceable in the cellar or warm cupboard records, *it must be concluded that this wide discrepancy is due to the difference in the ventilation of the incubators in summer and winter*. Throughout the whole course of these experiments the ventilators have been open as freely as possible consistent with the required percentage of humidity. This results in keeping the ventilators of the Wet incubators all but shut during the winter.

There is some evidence of seasonal difference in the powers of endurance of *P. irritans* to be gleaned from Table XI. The differences between the March and June series of *P. irritans* are probably due to individual variation and the small numbers used in the March experiments. The results of the later tests with larger numbers only show the influence of favourable or unfavourable conditions of humidity and temperature.

As will be seen from the tables, *X. cheopis* comes between *C. fasciatus* and *P. irritans* as regards its powers of endurance unfed. Tubes with cotton-wool plug and a little sand at the bottom gave a better result than the corked tubes with blotting-paper under moist and moderately cool conditions. With regard to the experiment in incubators 75 Dry on the 15th July, 1912, I am inclined to question the humidity record; the readings for a few days about this period were very irregular and quite abnormal and it is possible that the high records may have been merely snatch readings. If the humidity really averaged ·71, and did not sink below ·63, it is remarkable that the larvae lived so short a time.

Although *X. cheopis* is normally an inhabitant of hot climates, it is surprising that the newly-hatched larvae of this species are not able to survive hot and dry conditions any better than *C. fasciatus* (see Table XII).

A small trial with *Ct. canis* in July, 1911 (see Table XIII), suggests that this species is scarcely so well adapted to exist unfed as *P. irritans*; it is certainly very inferior in this respect to *C. fasciatus*.

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[1] Newly hatched larvae in small tubes might possibly be utilised as a method of testing the conditions of humidity prevailing in corners, holes in walls, etc. where it is not possible to take readings with an hygrometer.

Advantage is apparently taken by *C. fasciatus*, and possibly by *P. irritans* as well, of these powers of prolonged fasting to increase the variability of the brood in the matter of emergence. In some rearing experiments, it was noticed that the larvae when given food did not all commence to grow for varying periods of from several days to two or three weeks and a few larvae became no larger than when they emerged from the egg. Meanwhile their fellows of the same batch had attained their full growth.

To test the crawling powers of the freshly emerged unfed larvae, the tracks of several individuals of *C. fasciatus, P. irritans* (Fig. 2, p. 502) and *X. cheopis* (Fig. 3, p. 503) were followed with a pencil on sheets of paper, the tests lasting for 30 minutes in each case.

It will be noted that both *P. irritans* and *X. cheopis* seem better adapted for wandering in search of food than *C. fasciatus*. An attempt was also made with *C. fasciatus* and *X. cheopis* to ascertain if the freshly emerged larvae crawled quite at random or whether they showed any instinctive tendency to progress in the direction of food, moisture or cover.

Eleven newly hatched larvae of *C. fasciatus* were placed on a large sheet of white paper with the following substances arranged in a circle at equal distances from their starting point: (*a*) a piece of blood-soaked rag, (*b*) a piece of gauze spotted with flea faeces, (*c*) a piece of plain cloth, and (*d*) a pat of moist sand. The larvae crawled in various directions, but none went near the cloth; two approached quite close to the damp sand, but turned aside and wandered past it. Three came quite close to the gauze with the flea droppings on it, but seemed quite uninfluenced by the proximity of this food, and either wandered past it or turned back towards their starting point. None went anywhere near the blood-soaked rag. The only conclusion possible during the period of watching was that their wanderings were quite at random and in no way influenced by the various articles.

The experiment was repeated with *X. cheopis*, the only difference being that the flea-spotted gauze was replaced by dry sand. Fifteen newly hatched larvae were placed in a central circle and watched for 15 minutes, with the following result:

5 did not leave the circle.
1 reached the wet sand.
1 reached the dry sand.
1 reached the cloth.

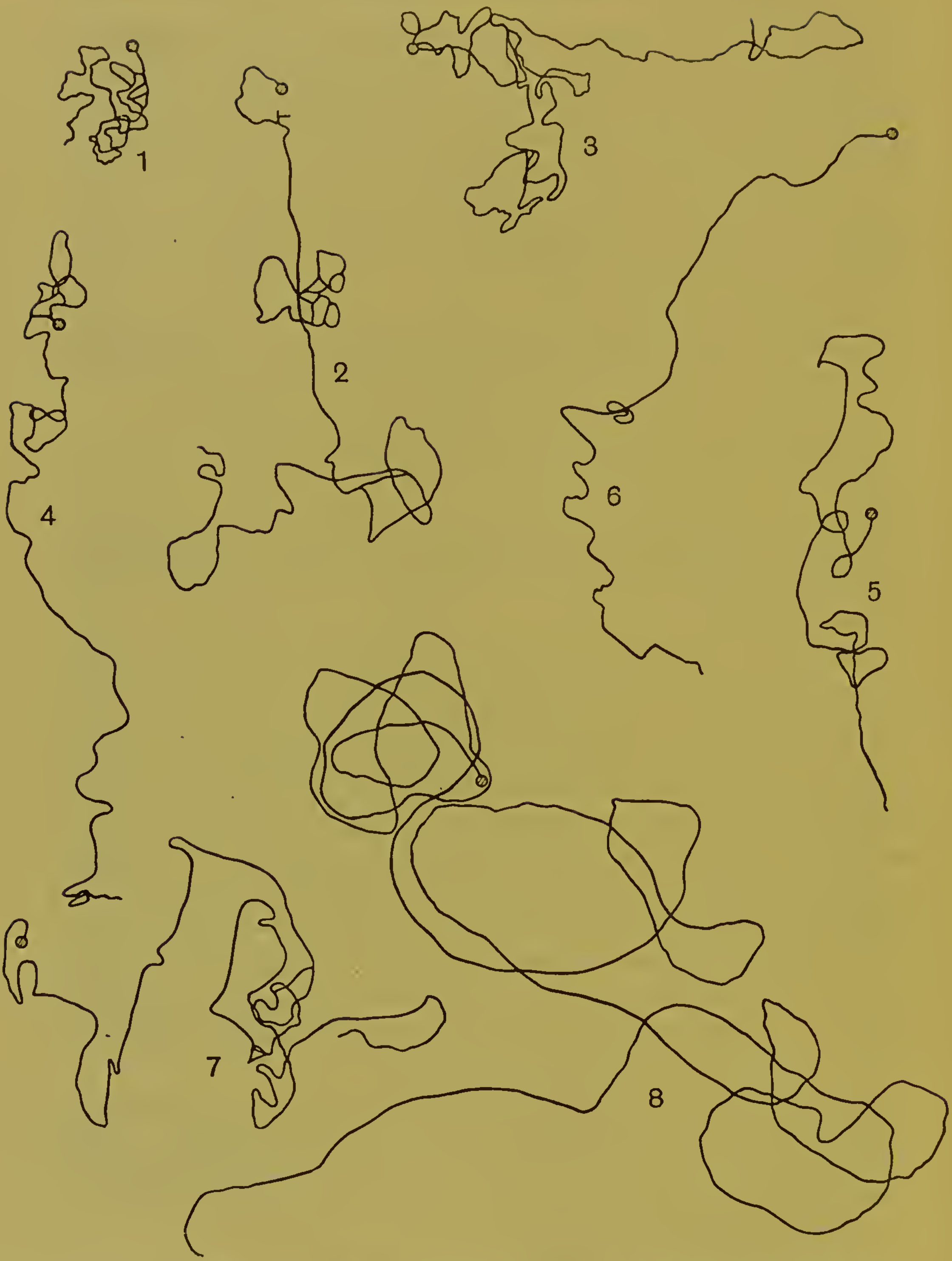

Fig. 2. 1. Larva of *C. fasciatus*. Newly hatched. 30 minutes on white paper. Distance = about 6 inches. 2. Larva of *C. fasciatus*. Newly hatched. 30 minutes on white paper. Distance = about 15 inches. 3. Larva of *C. fasciatus*. Newly hatched. 30 minutes on white paper. Distance = about 16 inches. 4. Larva of *C. fasciatus*. Newly hatched. 30 minutes on white paper. Distance = about 12 inches. 5. Larva of *C. fasciatus*. Newly hatched. On cork carpet 30 minutes. Distance = about 11 inches. 6. Larva of *C. fasciatus*. Newly hatched. On cork carpet 30 minutes. Distance = about 8 inches. 7. Larva *P. irritans*. Newly hatched. On cork carpet 30 minutes. Distance = about 18 inches. 8. Larva of *P. irritans*. Newly hatched. On white paper 30 minutes. Distance = about 42 inches.

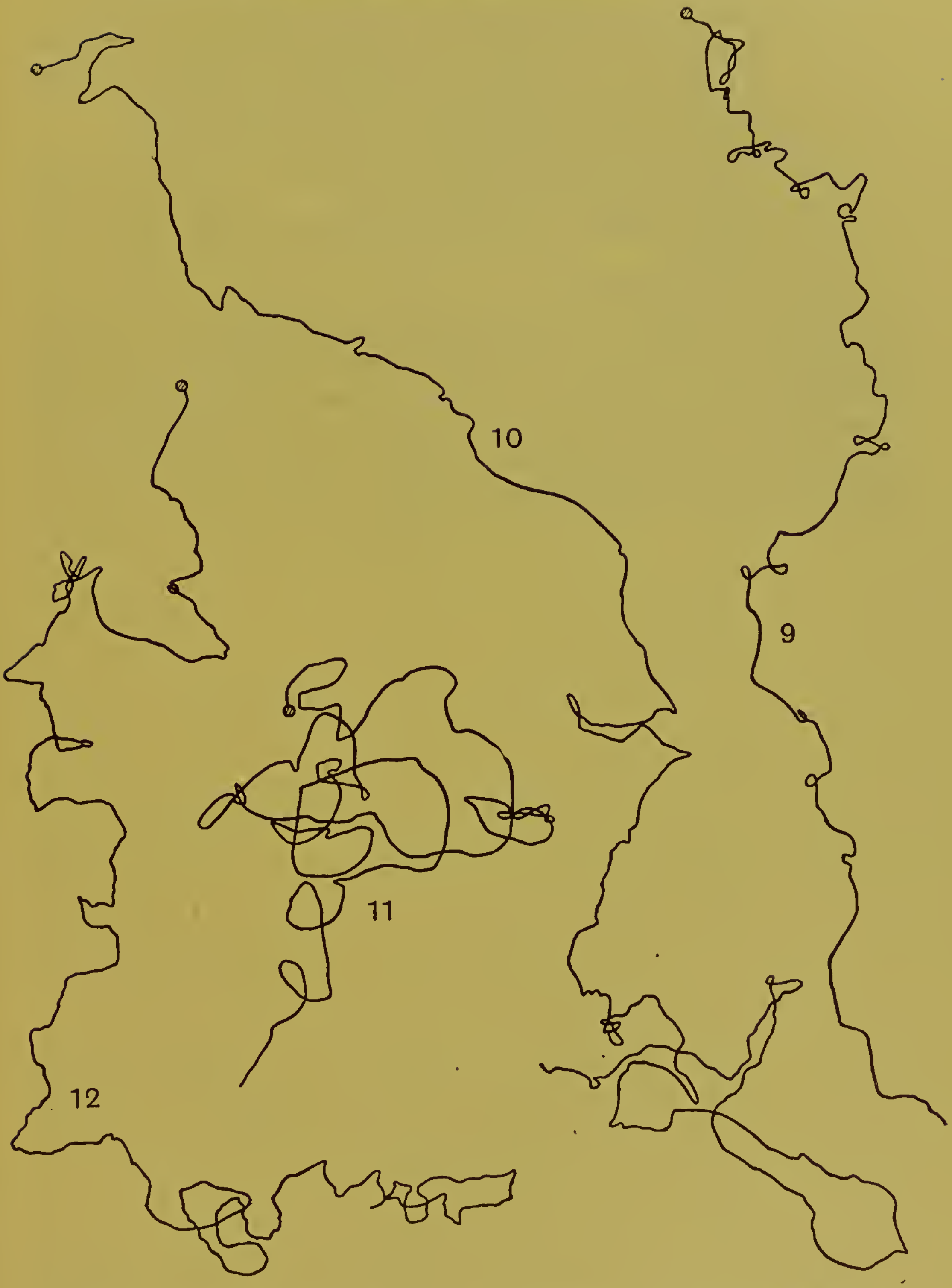

Fig. 3. 9. No. 1 Larva of *X. cheopis*. Newly hatched. On white paper 30 minutes. Distance = about 16 inches. 10. No. 2 Larva of *X. cheopis*. Newly hatched. On white paper 30 minutes. Distance = about 27 inches. 11. No. 3 Larva of *X. cheopis*. Newly hatched. On white paper 30 minutes. Distance = about 23 inches. 12. No. 4 Larva of *X. cheopis*. Newly hatched. On white paper 30 minutes. Distance = about 23 inches.

1 stopped to feed just before reaching the blood-soaked rag, presumably on a speck of dried blood which had become detached, as its alimentary canal at once darkened.

1 wandered out past and between the wet and dry sand.

3 remained sluggish after crawling about midway between the starting circle and the wet sand.

1 stopped between the starting circle, blood-soaked rag and the wet sand.

The larvae are, however, very prompt at attacking food in their immediate proximity. A larva has been seen to partake of a speck of flea faeces when placed in the lid of a small cardboard box that was apparently quite clean, but was found to have a few specks of flea droppings on it when carefully examined. It was a matter of a few seconds only for the perfectly white freshly emerged larvae to show a dark line as the food entered its stomach.

TABLE X. *Newly hatched larvae* C. fasciatus. *Experiment to determine length of life unfed. Series I.*

A. In corked tubes.

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail	Average life
13 Dec. '10	Cellar	max. min. 49 48	·93	8	2 dead in 9 days	23 days
					1 ,, 19 ,,	
					1 ,, 25 ,,	
					2 ,, 29 ,,	
					2 ,, 31 ,,	
14 Dec. '10	Incubator 75 Wet	74·4	·75	7	2 ,, 13 ,,	18 ,,
					2 ,, 18 ,,	
					1 ,, 20 ,,	
					2 ,, 24 ,,	
17 Dec. '10	Incubator 85 Wet	84·4	·69	8	2 ,, 10 ,,	14 ,,
					6 ,, 15 ,,	
18 Dec. '10	Lab. Cupboard	max. min. 53 44	·84	10	1 ,, 10 ,,	26 ,,
					2 ,, 16 ,,	
					2 ,, 26 ,,	
					2 ,, 29 ,,	
					1 ,, 33 ,,	
					2 ,, 39 ,,	
18 Dec. '10	Incubator 85 Dry	85	·59	10	4 ,, 3 ,,	5 ,,
					4 ,, 5 ,,	
					2 ,, 8 ,,	
19 Dec. '10	Incubator 75 Dry	76	·43	10	all ,, 3 ,,	3 ,,
19 Dec. '10	Warm Cupboard	64	·57	10	,, ,, 3 ,,	3 ,,
19 Dec. '10	Beehive	*max. min. 44 32		10	2 ,, 13 ,,	23 ,,
					7 ,, 23 ,,	
					1 ,, 39 ,,	
22 July '11	Warm Cupboard	74	·62	12	5 ,, 2 ,,	4 ,,
					3 ,, 4 ,,	
					1 ,, 5 ,,	
					3 ,, 7 ,,	
22 July '11	Beehive	max. min. 85·5 59·5	—	12	11 ,, 2 ,,	2·4 ,,
					1 ,, 7 ,,	
23 July '11	Lab. Cupboard	73·3 65·3	·73	12	6 ,, 2 ,,	6 ,,
					1 ,, 3 ,,	
					1 ,, 5 ,,	
					2 ,, 10 ,,	
					1 ,, 13 ,,	
					1 ,, 18 ,,	
23 July '11	Cellar	64·5 63·5	·94	12	1 ,, 2 ,,	26·2 ,,
					4 ,, 19 ,,	
					2 ,, 24 ,,	
					2 ,, 36 ,,	
					3 ,, 39 ,,	

* Average temperature for the last 29 days only.

TABLE X.—*continued.*

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail	Average life
23 July '11	Incubator 75 Wet	75·9	·82	12	2 dead in 3 days	10·8 days
					1 ,, 4 ,,	
					2 ,, 5 ,,	
					3 ,, 12 ,,	
					1 ,, 16 ,,	
					2 ,, 18 ,,	
					1 ,, 22 ,,	
23 July '11	Incubator 75 Dry	77·6	·52	12	9 ,, 1 day	1·3 ,,
					3 ,, 2 days	
23 July '11	Incubator 85 Wet	86	·82	12	5 ,, 1 day	3·3 ,,
					1 ,, 2 days	
					2 ,, 3 ,,	
					1 ,, 4 ,,	
					2 ,, 8 ,,	
					1 ,, 11 ,,	
23 July '11	Incubator 85 Dry	84	·68	12	10 ,, 1 day	1·4 ,,
					1 ,, 3 days	
					1 ,, 4 ,,	
29 Nov. '11	Incubator 75 Wet	75·8	·65	12	1 ,, 6 ,,	20 ,,
					1 ,, 13 ,,	
					3 ,, 20 ,,	
					2 ,, 23 ,,	
					3 ,, 24 ,,	
					1 ,, 25 ,,	
					1 ,, 26 ,,	
29 Nov. '11	Incubator 75 Dry	75·2	·49	12	all ,, 2 ,,	
29 Nov. '11	Incubator 92 Wet	92·5	·67	12	1 ,, 1 day	5 ,,
					1 ,, 3 days	
					1 ,, 4 ,,	
					1 ,, 5 ,,	
					5 ,, 6 ,,	
					3 ,, 7 ,,	
29 Nov. '11	Incubator 92 Dry	93·8	·57	12	3 ,, 1 day	3 ,,
					3 ,, 2 days	
					1 ,, 3 ,,	
					4 ,, 4 ,,	
					1 ,, 7 ,,	
		max. min.				
11 Dec. '11	Cellar	Dec. 48·7 47·4	·92	9	3 ,, 57 ,,	75 ,,
		Jan. 47·2 45·9	·92		2 ,, 64 ,,	
		Feb. 45·8 44·6	·92		2 ,, 77 ,,	
					1 ,, 101 ,,	
					1 ,, 120 ,,	
24 Dec. '11	Lab. Cupboard	Dec. 53·9 46·2	·87	10	2 ,, 5 ,,	34 ,,
		Jan. 52·5 44·9	·89		1 ,, 11 ,,	
		Feb. 54·4 45·3	·86		1 ,, 32 ,,	
					3 ,, 43 ,,	
					2 ,, 51 ,,	
					1 ,, 53 ,,	

TABLE X.—*continued.*

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail		Average life
24 Dec. '11	Warm Cupboard	60·4	·62	9	4 dead in	4 days	5 days
					4 ,,	6 ,,	
					1 ,,	7 ,,	
25 Dec. '11	Beehive	max. min. Dec. 46·8 35·0	—	12	2 ,,	5 ,,	50 ,,
		Jan. 43·6 34·0			2 ,,	10 ,,	
		Feb. 46·7 34·3			4 ,,	77 ,,	
					2 ,,	87 ,,	
					1 ,,	89 ,,	
25 Dec. '11	Incubator 92 Wet	92	·71	13	13 ,,	1 day	
26 Dec. '11	Incubator 92 Wet	92·5	·71	3	3 ,,	1 ,,	
B. Placed in small glass tubes containing a little sand and with cotton-wool plugs in place of corks.							
18 Mar. '12	Incubator 75 Wet	75·2	·80	10	2 ,,	11 days	17 ,,
					2 ,,	14 ,,	
					2 ,,	17 ,,	
					3 ,,	21 ,,	
					1 ,,	22 ,,	
18 Mar. '12	Incubator 75 Dry	72	·54	10	9 ,,	1 day	1 day
					1 ,,	2 days	
18 Mar. '12	Incubator 92 Wet	91·5	·68	10	3 ,,	4 ,,	6 days
					7 ,,	7 ,,	
18 Mar. '12	Incubator 92 Dry	92	·59	9	6 ,,	1 day	1 day
					2 ,,	2 days	
					1 ,,	3 ,,	
18 Mar. '12	Cellar	max. min. Mar. 49·1 48·1	·93	9	2 ,,	17 ,,	34 days
		Apr. 50·3 49·1	·93		2 ,,	22 ,,	
		May 54·2 53·2	·93		2 ,,	29 ,,	
					1 ,,	39 ,,	
					1 ,,	59 ,,	
					1 ,,	78 ,,	
18 Mar. '12	Beehive	Mar. 54·1 38·2	—	10	2 ,,	7 ,,	29 ,,
		Apr. 64·1 37·3			1 ,,	11 ,,	
					1 ,,	14 ,,	
					2 ,,	17 ,,	
					1 ,,	22 ,,	
					1 ,,	26 ,,	
					1 ,,	33 ,,	
					1 ,,	35 ,,	
Mar. '12	Warm Cupboard	57·5	·63	10	all ,,	2 ,,	
18 Mar. '12	Lab. Cupboard	max. min. 54·4 45·5	·86	10	3 ,,	3 ,,	7 ,,
					3 ,,	7 ,,	
					3 ,,	10 ,,	
					1 ,,	12 ,,	

TABLE XI. *Newly hatched larvae* P. irritans. *Experiment to determine length of life unfed.*

A. In corked tubes.

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail	Average life
15 Mar. '11	Incubator 85 Dry	84	·55	1	1 dead in 2 days	2 days
14 Mar. '11	Incubator 75 Dry	75	·48	3	1 ,, 1 day	3 ,,
					1 ,, 3 days	
					1 ,, 5 ,,	
16 Mar. '11	Incubator 85 Wet	83	·70	3	3 ,, 1 day	1 day
17 Mar. '11	Incubator 85 Wet	83	·70	1	1 ,, 1 ,,	
13 Mar. '11	Incubator 75 Wet	74	·76	6	4 ,, 5 days	6 days
					2 ,, 7 ,,	
18 Mar. '11	Lab. Cupboard	max. min. 56 47	·86	2	1 ,, 12 ,,	13 ,,
					1 ,, 15 ,,	
19 Mar. '11	Beehive	55 34	—	4	1 ,, 4 ,,	19 ,,
					2 ,, 24 ,,	
					1 ,, 26 ,,	
20 Mar. '11	Cellar	46 44	·92	4	2 ,, 15 ,,	18 ,,
					1 ,, 19 ,,	
					1 ,, 23 ,,	
21 Mar. '11	Warm Cupboard	61	·61	2	1 ,, 1 day	5 ,,
					1 ,, 9 days	
24 Mar. '11	Incubator 75 Wet	75	·74	4	4 ,, 6 ,,	
3 April '11	Incubator 75 Wet	75	·76	8	2 ,, 4 ,,	6 ,,
					5 ,, 7 ,,	
					1 ,, 10 ,,	
3 April '11	Incubator 85 Wet	84	·68	6	1 ,, 1 day	4 ,,
					1 ,, 3 days	
					2 ,, 4 ,,	
					1 ,, 5 ,,	
					1 ,, 6 ,,	
*21 June '11	Cellar	max. min. 58 57	·93	12	6 ,, 9 ,,	12 ,,
					5 ,, 14 ,,	
					1 ,, 19 ,,	
*21 June '11	Lab. Cupboard	63 59	·85	12	2 ,, 5 ,,	9 ,,
					9 ,, 9 ,,	
					1 ,, 12 ,,	
†22 June '11	Incubator 85 Dry	83	·68	12	4 ,, 2 ,,	3 ,,
					8 ,, 3 ,,	
†22 June '11	Incubator 85 Wet	84	·79	12	5 ,, 4 ,,	5 ,,
					5 ,, 5 ,,	
					2 ,, 6 ,,	
‡26 June '11	Incubator 75 Wet	75	·74	12	3 ,, 3 ,,	4 ,,
					8 ,, 4 ,,	
					1 ,, 5 ,,	
‡26 June '11	Incubator 75 Dry	75	·55	12	12 ,, 1 day	1 day

* Batches of larvae were divided on each date * † ‡.

TABLE XI.—*continued.*

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail	Average life
20 July '11	Incubator 75 Wet	76·5	·82	12	3 dead in 4 days	6 days
					8 ,, 6 ,,	
					1 ,, 8 ,,	
20 July '11	Incubator 75 Dry	77	·56	12	5 ,, 2 ,,	3 ,,
					4 ,, 3 ,,	
					2 ,, 4 ,,	
					1 ,, 5 ,,	
20 July '11	Incubator 85 Wet	85·8	·83	12	3 ,, 3 ,,	4 ,,
					4 ,, 4 ,,	
					5 ,, 5 ,,	
20 July '11	Incubator 85 Dry	84	·72	12	4 ,, 2 ,,	3 ,,
					8 ,, 3 ,,	
22 July '11	Cellar	max. min. 64 63	·94	12	3 ,, 3 ,,	6 ,,
					2 ,, 4 ,,	
					6 ,, 6 ,,	
					1 ,, 14 ,,	
22 July '11	Lab. Cupboard	75·2 66·7	·70	12	8 ,, 3 ,,	4 ,,
					3 ,, 6 ,,	
					1 ,, 7 ,,	
22 July '11	Warm Cupboard	75	·60	12	8 ,, 2 ,,	2 ,,
					2 ,, 3 ,,	
					2 ,, 4 ,,	
22 July '11	Beehive	max. min. 86 59	—	12	1 ,, 2 ,,	4 ,,
					8 ,, 4 ,,	
					2 ,, 5 ,,	
					1 ,, 6 ,,	
29 Nov. '11	Incubator 75 Wet	76·5	·67	11	2 ,, 2 ,,	5 ,,
					4 ,, 5 ,,	
					2 ,, 6 ,,	
					2 ,, 7 ,,	
					1 ,, 8 ,,	
29 Nov. '11	Incubator 75 Dry	75·2	·49	11	all ,, 2 ,,	
29 Nov. '11	Incubator 92 Wet	92	·66	11	,, ,, 1 day	
29 Nov. '11	Incubator 92 Dry	93·7	·57	11	9 ,, 1 ,,	1 day
					2 ,, 2 days	
2 Dec. '11	Warm Cupboard	64·6	·59	12	1 ,, 2 ,,	3 days
					7 ,, 3 ,,	
					4 ,, 4 ,,	
11 Dec. '11	Cellar	max. min. 48·8 47·7	·93	12	4 ,, 11 ,,	14 ,,
					2 ,, 14 ,,	
					2 ,, 15 ,,	
					2 ,, 16 ,,	
					1 ,, 18 ,,	
					1 ,, 20 ,,	

TABLE XI.—*continued.*

Date	Place	Temperature	Average Humidity	Number put into tubes	Detail	Average life
11 Dec. '11	Lab. Cupboard	max. min. 54·4 47·4	·87	12	3 dead in 8 days	10 days
					9 ,, 11 ,,	
12 Dec. '11	Beehive	47·4 35·2	—	12	7 ,, 4 ,,	7 ,,
					2 ,, 7 ,,	
					2 ,, 10 ,,	
					1 ,, 23 ,,	
B. In small glass tubes plugged with cotton-wool and a little sand at bottom.						
1 Jan. '12	Incubator 75 Wet	76·8	·65	10	3 ,, 2 ,,	4 ,,
					2 ,, 3 ,,	
					5 ,, 5 ,,	
1 Jan. '12	Incubator 92 Wet	93·5	·68	10	3 ,, 1 day	2 ,,
					3 ,, 2 days	
					4 ,, 3 ,,	
1 Jan. '12	Incubator 92 Dry	94	·54	10	6 ,, 1 day	1 day
					4 ,, 2 days	
1 Jan. '12	Incubator 75 Dry	75·5	·49	10	4 ,, 2 ,,	3 days
					4 ,, 3 ,,	
					2 ,, 4 ,,	
20 Jan. '12	Cellar	max. min. 46·2 44·5	·92	10	3 ,, 5 ,,	9 ,,
					5 ,, 10 ,,	
					2 ,, 14 ,,	
20 Jan. '12	Beehive	43·2 35·1	—	10	7 ,, 5 ,,	6 ,,
					2 ,, 7 ,,	
					1 ,, 9 ,,	
22 Jan. '12	Warm Cupboard	58·5	·63	10	8 ,, 2 ,,	2 ,,
					2 ,, 3 ,,	
22 Jan. '12	Lab. Cupboard	max. min. 51·1 42·8	·90	10	4 ,, 4 ,,	7 ,,
					3 ,, 8 ,,	
					3 ,, 12 ,,	
25 Jan. '12	Incubator 75 Dry	75	·52	10	8 ,, 1 day	1 day
					2 ,, 2 days	
26 Jan. '12	Incubator 75 Wet	75·6	·71	10	6 ,, 5 ,,	6 days
					3 ,, 8 ,,	
					1 ,, 10 ,,	
29 Jan. '12	Incubator 93 Wet	93	·65	10	4 ,, 2 ,,	3 ,,
					6 ,, 3 ,,	
29 Jan. '12	Incubator 93 Dry	94	·56	10	2 ,, 1 day	2 ,,
					7 ,, 2 days	
					1 ,, 3 ,,	
30 Jan. '12	Beehive	max. min. 40 27	—	10	all ,, 4 ,,	
	Daily readings	41 26				
		36 19				
		42 12				
30 Jan. '12	Cellar	40·5 39·4	·91	10	7 ,, 7 ,,	9 ,,
					2 ,, 14 ,,	
					1 ,, 16 ,,	

TABLE XII. *Newly hatched larvae* X. cheopis. *Experiment to determine length of life unfed.*

A. In corked tubes.

Date	Place	Temperature max. min.	Average Humidity	Number put in tubes	Detail	Average life
14 June '11	Cellar	57 56	·93	6	2 dead in 12 days	16 days
					2 ,, 16 ,,	
					2 ,, 19 ,,	
4 Sept. '11	Cellar	60 58	·93	12	2 ,, 10 ,,	19 ,,
					3 ,, 14 ,,	
					1 ,, 16 ,,	
					2 ,, 18 ,,	
					3 ,, 28 ,,	
					1 ,, 30 ,,	
4 Sept. '11	Lab. Cupboard	67 58	·75	12	3 ,, 8 ,,	10 ,,
					4 ,, 10 ,,	
					2 ,, 11 ,,	
					1 ,, 12 ,,	
					2 ,, 15 ,,	
4 Sept. '11	Incubator 75 Wet	74·8	·76	12	3 ,, 7 ,,	11 ,,
					4 ,, 10 ,,	
					2 ,, 12 ,,	
					1 ,, 14 ,,	
					1 ,, 15 ,,	
					1 ,, 26 ,,	
4 Sept. '11	Incubator 85 Wet	84·9	·79	12	4 ,, 4 ,,	6 ,,
					6 ,, 6 ,,	
					2 ,, 8 ,,	
28 Sept. '11	Incubator 85 Dry	84·9	·57	12	4 ,, 4 ,,	5 ,,
					7 ,, 5 ,,	
					1 ,, 6 ,,	
28 Sept. '11	Incubator 75 Dry	75	·50	12	9 ,, 2 ,,	2 ,,
					3 ,, 3 ,,	
28 Sept. '11	Warm Cupboard	67	·64	12	12 ,, 3 ,,	3 ,,
11 Dec. '11	Incubator 75 Wet	75·6	·67	7	4 ,, 11 ,,	12 ,,
					1 ,, 13 ,,	
					1 ,, 14 ,,	
					1 ,, 15 ,,	
11 Dec. '11	Incubator 92 Wet	92·1	·67	7	2 ,, 2 ,,	4 ,,
					1 ,, 4 ,,	
					2 ,, 5 ,,	
					2 ,, 6 ,,	
24 Dec. '11	Incubator 75 Dry	74·7	·51	9	1 ,, 2 ,,	5 ,,
					4 ,, 4 ,,	
					3 ,, 6 ,,	
					1 ,, 7 ,,	
13 July '12	Incubator 93 Wet	95·2	·83	8	5 ,, 2 ,,	3 ,,
					2 ,, 3 ,,	
					1 ,, 5 ,,	
15 July '12	Incubator 93 Dry	93	·69	6	5 ,, 1 day	1 day
					1 ,, 2 days	

TABLE XII.—*continued.*

Date	Place	Temperature	Average Humidity	Number put in tubes	Detail	Average life
15 July '12	Incubator 75 Dry	77·5	·71*	6	3 dead in 1 day	1 day
					3 ,, 2 days	
B. Placed in small glass tubes with a little fine sand; the tubes plugged with cotton-wool.						
4 Aug. '12	Incubator 75 Wet	74·7	·81	6	3 ,, 13 ,,	17 days
					3 ,, 22 ,,	
4 Aug. '12	Incubator 75 Dry	75	·64	6	5 ,, 1 day	1 day
					1 ,, 2 days	
4 Aug. '12	Incubator 93 Wet	93·3	·78	6	2 ,, 1 day	5 days
					1 ,, 4 days	
					1 ,, 6 ,,	
					2 ,, 9 ,,	
4 Aug. '12	Incubator 93 Dry	93	·54	6	6 ,, 1 day	1 day or less
5 Aug. '12	Warm Cupboard	65·1	·72	4	1 ,, 2 days	4 days
					1 ,, 4 ,,	
					2 ,, 6 ,,	
5 Aug. '12	Cellar Aug. Sept.	max. min. 57·5 56·5	·93	6	2 ,, 10 ,,	22 ,,
					1 ,, 12 ,,	
					1 ,, 29 ,,	
					2 ,, 35 ,,	
15 Aug. '12	Lab. Cupboard	62·4 54·5	·86	6	1 ,, 5 ,,	20 ,,
					1 ,, 15 ,,	
					1 ,, 20 ,,	
					1 ,, 25 ,,	
					1 ,, 28 ,,	
					1 ,, 30 ,,	
15 Aug. '12	Beehive	64·5 44·7	—	6	1 ,, 4 ,,	21 ,,
					1 ,, 19 ,,	
					1 ,, 22 ,,	
					1 ,, 25 ,,	
					2 ,, 28 ,,	

* Humidity very irregular; varied from ·79 to ·63.

TABLE XIII. *Newly hatched larvae* Ct. canis. *Experiment to determine length of life unfed.*

In corked tubes.

Date	Place	Temperature	Average Humidity	Number put in tubes	Detail	Average life
29 July '11	Incubator 75 Wet	76	·85	10	6 dead in 2 days	4 days
					2 ,, 4 ,,	
					1 ,, 6 ,,	
					1 ,, 10 ,,	
29 July '11	Incubator 75 Dry	77·7	·59	10	7 ,, 2 ,,	3 ,,
					3 ,, 4 ,,	
29 July '11	Cellar	max. min. 63 62	·94	10	4 ,, 3 ,,	6 ,,
					5 ,, 7 ,,	
					1 ,, 13 ,,	

(ii) *Influence of temperature, humidity and nature of the food supply upon rearing.* The chief factors influencing the larval life of the species experimented on appear to be humidity of the air, temperature, and food supply. A situation sufficiently dry to ensure that dust and fine sand do not cling is essential for rearing larvae, while at the same time the percentage of humidity in the air in their immediate proximity should be above a mean of ·60 to ·65. It is of course probable that owing to local moistening larvae may thrive amid what are otherwise impossible circumstances. For example, the margins of a periodically wetted area in a very dry place would give limited but quite feasible opportunities for larval life; being very active crawlers, the larvae could easily keep to the margins, even if the area fluctuated in size. The numerous instances of larvae quitting their cocoons shortly after spinning, when the latter were subjected to hot, dry conditions, may indicate an instinct on the part of the larva, if an unfavourable change occurs, to search for a more suitable situation for its metamorphosis, even after the cocoon has been formed.

While it is difficult to fix exact limits to the range of temperature to which larvae can adjust themselves, it is certain that unfavourable, but not necessarily fatal conditions, may enormously delay development. Cold delays development in some species, and is fatal to others.

As regards food, the range of possible diet is no doubt a wide one, as already noted in the Committee's Report (Vol. VIII, No. 2, May 1908, *Journal of Hygiene*), but some of my experiments have shown that all the species are not alike in this respect and that some do not succeed on food that gives good results for others.

P. irritans is not so particular about its food as *C. fasciatus*; it can also survive in draughty situations or under conditions of humidity that are fatal to *C. fasciatus*.

X. cheopis appears to resemble *P. irritans*, rather than its congener, in the matter of food, but is more susceptible to cool conditions than the other species dealt with, and possibly better able to resist dry heat. This difference in adaptability on the part of *X. cheopis* and *C. fasciatus* in respect to food has probably a direct relation to the habits of their hosts, assuming, as I do, that the Committee's Report ("On the Bionomics of Fleas," Vol. VIII, No. 2, p. 245, May 1908, *Journal of Hygiene*) is correct in considering *M. rattus* as the host of *X. cheopis* and *M. decumanus* as the host of *C. fasciatus*. *M. rattus* is apparently chiefly to be found in houses, warehouses, granaries, etc., places which would be likely to offer many situations in which larvae might be reared quite apart from their hosts, provided that they could make shift on a diet devoid of their parents' droppings. On the other hand, *M. decumanus*, as an inhabitant of sewers and cellars, is more associated with the ground level or beneath it and occupies situations which are less likely to afford suitable places for the rearing of larvae apart from the nests of their hosts. The habits of the two fleas fit those of their respective hosts. Compared with *C. fasciatus, X. cheopis* is far more closely attached to the rat; accustomed to travel with its host, it can afford to drop some of its eggs with a fair chance of the resulting larvae being reared. Although, under these circumstances, the droppings of the adult fleas are likely to be thinly scattered over a wide area, this need not prove disastrous for rearing the larvae of this species which are not entirely dependent upon food in this form. Supposing that the adults of *C. fasciatus* had the same habit of clinging to the rat that *X. cheopis* has, such a habit would be unduly wasteful, as numbers of ova might fall in places where there would be no chance of a food supply other than the thinly scattered flea droppings.

The cool, and probably more humid, situations in which *M. decumanus* must frequently nest, would make it advantageous for the adult fleas to wait quite a considerable time for the return of their host to the nest, for among the haunts of the animal it is likely to be one of the few favourable situations for flea breeding.

C. fasciatus. The experiments (see Tables XV to XVIII) show that a cool situation with a humid atmosphere is most favourable to the larvae of this species, but that temperature up to 85° F. may be survived by some individuals; low humidities at any temperature will prove fatal to active larvae. Under the conditions of the tests the critical point of humidity was found to be in the neighbourhood of ·60 to ·65 for temperatures up to 75° F. in a still atmosphere. With a draughty situation a considerably higher humidity is necessary for success in rearing from the egg—note the persistent mortality in the laboratory cupboard, which, in spite of its high percentage of humidity, gave scarcely any successful results (see Exp. *h*, Table XVI).

Moistening with either water or urine will mitigate a condition of extreme drought in which no larvae can survive for longer than a day or two. If liquid be applied in suitable quantities at regular intervals, breeding is possible. Moistening may, however, be easily overdone if applied injudiciously; there is some possibility that urine is a more effective moistening agent than water[1].

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[1] These moistening experiments were instituted as it was thought that the possibility of children urinating within a house or hut with earth floors, or damping of the floor from

From the experiments detailed in Table XV, the nature of the food supplied to larvae even when well grown is seen to be of importance. The fact that, in so humid a place as the cellar, there is so large a difference in the mortality of those nourished on rat faeces 80 % or B.S. rag 40 % respectively, suggests that the difference is really one of nutrition, and is not due to the mechanical difficulty of absorbing dry food from large masses. This point is further emphasised in Table XVI in the series carried out during May, June and July 1911 in the cellar and incubators 85 Wet and 75 Wet respectively, to test the relative values as food of B.S. rag, flea faeces and crushed rat faeces for *C. fasciatus.* The May series (in incubator 75 Wet) (Exp. *a*, Table XVI) consisted of a batch of young larvae from eggs laid and hatched under precisely similar conditions and then divided on the same date between the experiments. It will be noted that, while the flea faeces and B.S. rag batches showed a mortality of 29 % in both cases, the mortality with rat faeces as food was 100 %. A similar result is also apparent with experiments in the cellar on the 18th and 25th June (Exp. *f*, Table XVI) and in incubator 85 Wet on the 8th and 13th July (Exp. *c*, Table XVI), but in these cases the larvae under different dates were from separate layings.

When nourished on different diets, the speed with which larvae attain the cocoon stage varies considerably, conditions other than food being similar. The results obtained are somewhat contradictory, in some cases flea faeces and at others B.S. rag showing an advantage. These discrepancies are probably due to more than one cause. Firstly, the innate variability of the species must be taken into account and, secondly, the food supplied was not properly standardised. Flea faeces, which consist of the dejecta of *P. irritans* on the gauze coverings of the boxes in which they are kept, have possibly been given in varying quantities, it being no easy matter to gauge the exact quantity, and the B.S. rag has differed in quality, that is, in regard to the amount of blood on it. Three different cloths have been used since the commencement of the experiments, the second being decidedly inferior, while the last was much the best. It was not, unfortunately, anticipated that difference in quality of food would be of such great importance to

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any cause might make all the difference between the extermination or survival of flea larvae during the dry season. The urination of rats, especially nestling rats, will certainly be an important factor in the relative scarcity or abundance of fleas in hot, dry climates. The factor of local moistening is of course applicable when fleas are reared on caged rats.

the larvae as now appears probable in the light of the experiments. The rationale of the matter seems to be that the best food gives the quicker development as well as the lowest mortality.

P. irritans. The results with this species largely resemble those obtained with *C. fasciatus* as regards conditions of temperature and humidity, but at the same time there is evidence of its being a hardier species, with greater ability to survive in hot and dry conditions. This is most clearly shown by its survival under cool, draughty conditions in the laboratory cupboard (see Exp. *g*, Table XXI), in which place hardly one larva of *C. fasciatus* was reared (see Exp. *h*, Table XVI). Further testimony is available from the hot Wet incubator series of the two species, a few individuals of *P. irritans* having been reared at a temperature of 93° F. (see Exp. *c*, Table XXI, Jan. 25 and Mar. 22, 1912).

The experiments of feeding on rat faeces and bran show that this species is also more adaptable in the matter of food. Probably the advance in human comfort and cleanliness will have gradually forced the larvae of *P. irritans* to abandon dependence they may once have had upon a diet having origin in the blood of their parents' host.

X. cheopis. A low percentage of humidity in the air is as fatal to this species as it is to *C. fasciatus* and *P. irritans.* Table XXV shows that the conditions in incubators 85 Dry and 75 Dry are quite as impossible for it as for the other species dealt with, although there is some hint (see warm cupboard under date of 4th September 1911, and incubator 85 Dry 28th August 1911 (Table XXV)) that the larvae have greater powers of endurance than those of *C. fasciatus* and *P. irritans*, and the evidence afforded by the tests applied to newly hatched unfed larvae is, on the whole, of a confirmatory character (see Table XII). On the other hand, the tests of transferring well grown larvae of the rat fleas from the cages to incubators to complete their metamorphosis are hardly in agreement (compare Table XIX with Table XV), and suggest that *C. fasciatus* is even better adapted to the exigence of a sudden rise in temperature than its congener. This is not, however, necessarily contradictory to the view that *X. cheopis* is better adapted for breeding under hot conditions than *C. fasciatus*, but rather that the latter is better able to resist a sudden change.

In Table XXV where comparison is made of the results obtained with *C. fasciatus*, *P. irritans* and *X. cheopis* under similar conditions it will be noticed that there is a lower mortality among *X. cheopis* reared in incubator 85 Wet and 75 Wet, which is reversed in the cooler situations. It is evident that cold, or even cool, conditions are very fatal to *X. cheopis*. The cellar, laboratory cupboard and beehive experiments in Table XXV, as well as Table XIX, dealing with the transfer of last instar larvae from the cages, show clearly that *X. cheopis* is ill adapted to survive the cold of English autumn conditions.

Ct. canis (Table XXIV). Sufficient ova of this species were obtained from a dog's bed to permit of a small experimental test upon rearing the larvae under varied conditions of temperature and humidity.

The larvae were all hatched from eggs laid in incubator 75 Wet and then distributed in batches as usual. The species would appear to be very intolerant of extreme conditions during its active larval life and, so far as it is safe to judge from this one experiment, cool and draughty situations are most suitable for its development.

MITES. Attempts to feed larvae on oatmeal, or to use oatmeal in place of sand with other foods, failed with *C. fasciatus* (see Table XVI under date of 14th February), and similar attempts with *P. irritans* in incubator 75 Wet, 85 Wet, the cellar and laboratory cupboard, on a more elaborate scale, gave like results. In all cases the jars developed swarms of mites, and the larvae disappeared, leaving no trace of remains.

Two direct tests were made in order to see if the mites were responsible for the failure.

With *P. irritans* two tubes were prepared with the necessary sand and B.S. rag. Into one numbers of mites and 11 newly hatched larvae were placed; in the other a few mites only and 12 half-grown larvae; both tubes were kept in incubator 75 Wet. Within nine days all trace of the newly hatched larvae had disappeared. The tube containing the half-grown larvae produced nine fleas.

With *C. fasciatus* the following experiment was carried out: half-grown larvae were taken from the cages and a batch of 14 placed in each of two tubes prepared as follows: tube No. 1 contained sand, oatmeal and B.S. rag, and was quite free from mites; tube No. 2 contained exactly the same, but with the addition of swarms of mites. The quantity of food was large in order that there might be no question of scarcity of food. Twelve fleas were reared from tube No. 1 and twelve from tube No. 2, the average time in both cases being 19 days.

The factors of extermination would appear therefore to be the mites, but they appear to be inimical only to flea larvae while they are young; most probably the flea larvae are destroyed when moulting, as the latter are then too sluggish to resist or to get away.

TABLE XV. *Development of larvae,* C. fasciatus. *Influence of temperature, humidity and food supply upon larvae taken from the breeding cages when half to full grown.*

Date	No. of larvae	Receptacle	Place	Food	Temp.	Humidity	No. of cocoons found	No. of fleas reared	Mortality	No. of days start to emergence	No. of days in cocoon	Remarks
25 July '10	19	Card jar	Incubator 85 Wet	Rat faeces	85	about ·72	—	1	95 %	14	—	
26 ,,	15	,,	,, 75 Wet	,,	75	,, ·67	—	1	93	20	—	
27 ,,	14	,,	Lab. cupboard	,,	about 60	,, ·84	—	2	86	1 took 26 1 ,, 29	—	
29 ,,	20	,,	Cellar	,,	max. 55·9 min. 54·6	,, ·93	—	4	80	1 ,, 27 1 ,, 31 1 ,, 63 1 ,, 125	1 took 50	1 active larva seen 73 days after start
3 Aug. '10	18	,,	Warm cupboard	,,	69·9 67·8	,, ·60	2	4	78	2 ,, 12 1 ,, 16 1 ,, 19	1 ,, 13 1 ,, 15 1 ,, 30	
8 ,,	25	,,	Incubator 85 Wet	B. S. Rag	84·8	·72	8	18	24	3 ,, 9 2 ,, 13 2 ,, 17 4 ,, 20 2 ,, 21 1 ,, 22 1 ,, 30 1 ,, 35 1 ,, 40 1 ,, 51		
9 ,,	21	,,	Incubator 75 Wet	,,	74·3	·69	5	19	10	1 ,, 10 1 ,, 13 12 ,, 16 3 ,, 19 2 ,, 20	1 ,, 10 3 ,, 11 1 ,, 12	
11 ,,	19	,,	Lab. cupboard	,,	about 60	about ·84	4	15	21	1 ,, 34 4 ,, 36 2 ,, 41 4 ,, 43 2 ,, 45 1 ,, 50 1 ,, 53	1 ,, 24 1 ,, 25 1 ,, 28	
12 ,,	16	,,	Cellar	,,	max. 59·0 min. 57·9	about ·93	1	9	44	1 ,, 35 2 ,, 38 1 ,, 49 4 ,, 51 1 ,, 55		
13 ,,	15	,,	Warm cupboard	,,	70·2 67·8	about ·60	—	0	100			2 active larvae seen 27 days after start
15 ,,	23	,,	Incubator 75 Wet	,,	74·5	·70	—	13	44	2 ,, 16 2 ,, 24 2 ,, 26 4 ,, 30 1 ,, 32		

16 ,,	25	,,	Lab. cupboard	,,	about 60	about ·84	14	19	24	2 ,, 23 2 ,, 25 1 ,, 27 2 ,, 29 1 ,, 31 1 ,, 34 3 ,, 35 2 ,, 42 1 ,, 46 1 ,, 49 1 ,, 53 2 ,, 59		
30 Sept. '10	23	,,	Lab. cupboard	,,	about 60	about ·84	—	15	35	1 ,, 26 4 ,, 38 2 ,, 40 2 ,, 49 2 ,, 54 1 ,, 59 2 ,, 75 1 ,, 81		
17 Aug. '10 19 ,, 22 ,, 25 ,, 15 Sept. '10 19 ,, Av. date, 31 Aug.	13 9 8 20 23 10 83	,,	Lab. cupboard	B.S. Rag	up to Nov. approximate 60 from Nov. to close of expt. max. min. 54·9 44·5	·84 ·84	9	58	30	Approximate Shortest max. 26 Average 45 Longest min. 114		
29 Dec. '10	14	Tube	Beehive	B.S. Rag	Jan. 43·9 32·0 Feb. 43·8 30·7 March 52·5 33·3 April 61·7 36·8 May 72·8 45·2 June 73·0 56·5 July 80·3 58·6 Aug. 80·2 57·6 Sept. 75·3 48·0 Oct. 61·9 41·3		11	9	36	1 took 148 1 ,, 152 3 ,, 158 1 ,, 180 1 ,, 211 2 ,, 300	2 took 129 2 ,, 135 1 ,, 131 1 ,, 153 1 ,, 178 1 ,, 218 1 ,, 267	4 cocoons opened 30 Sept. '11 contained 2 living pupae, 2 empty. Remaining cocoons opened 16 Nov. '11, all were empty
9 Sept. '12	22	Card jar	Incubator 75 Dry	B.S. Rag	75·0	·52	—	—	100	—	—	1 larva attempted to spin
,,	22	,,	,, 93 Dry	,,	92·0	·53	—	—	100	—	—	

TABLE XVI*. *Development of larvae,* C. fasciatus. *Influence of temperature, humidity and food supply upon larvae reared from egg; all eggs laid in incubator "75 Wet."*

Date	Tube	Box	Jar	Food	No. of larvae	Temperature	Humidity	Length of larval life to cocoon stage (in days)			Maximum number of days after hatching during which larvae were observed	No. of fleas reared	Mortality
								Min.	Aver.	Max.			
(*a*) Incubator 75 Wet.													
30 July '10	×	—	—	B.S. Rag	2	75	unrecorded	—	—	—	6	0	100 %
5 Aug. '10	×	—	—	,,	4	75	·66	—	—	—	25	0	100
11 ,,	—	×	—	,,	6	75	·70	—	—	—	3	0	100
24 Sept. '10	—	—	×	,,	16	75	·72	20	21	22	—	8	50
30 ,,	—	—	×	Dead flies (*M. domestica*)	6	—	—	9	12	17	—	6	Nil
16 Oct. '10	×	—	—	Rat faeces	15	74·3	·75†	—	14	—	—	1	93
19 ,,	—	×	—	B.S. Rag	9	74·3	·69†	—	—	—	—	0	100
30 ,,	×	—	—	,,	15	74·2	·74	13	15	18	—	13	13
30 ,,	×	—	—	Rat faeces	13	74·2	·74	15	16	18	—	8	38
21 Dec. '10	—	—	×	B.S. Rag	28	74·3	·75	19	25	39	—	8	72
14 Feb. '11	×	—	—	‡Oatmeal	10	74·4	·76	—	—	—	23	0	100
14 ,,	×	—	—	‡Oatmeal and B.S. Rag	14	74·4	·76	—	—	—	23	0	100
14 ,,	×	—	—	‡Oatmeal and flea faeces	12	74·4	·76	—	—	—	20	0	100
14 Mar. '11	×	—	—	Rat faeces crushed	26	75	·80	20	28	45	59	5	81
24 April '11	×	—	—	Powdered blood, no sand	8	74·7	·83	—	24	—	—	4	50
23 May '11	—	—	×	Flea faeces	28	75·8	·84	15	18	20	—	20	29
23 ,,	—	—	×	Rat faeces crushed	28	75·8	·84	15	17	20	34	0	§100
23 ,,	—	—	×	B.S. Rag	28	75·8	·84	15	17	22	—	20	29
14 Nov. '11	—	—	×	Bran	22	75·0	·69	—	—	—	32	0	100
Moistening test (see also Table XVII).													
13 Jan. '11	×	Moistened		B.S. Rag	13	74·4	—	21	24	33	37	8	38
13 ,,	×	Not moistened		,,	14	74·4	·75	—	—	—	35	0	100
(*b*) Incubator 75 Dry.													
21 Dec. '10	—	—	×	B.S. Rag	14	76·5	·41				No larvae seen after emergence	0	100
15 Mar. '11	×	—	—	Rat faeces crushed	20	74·5	·49				No larvae seen after placing in tube	0	100
28 Aug. '11	—	—	×	B.S. Rag	11	74·5	·61				1 larva seen after 2 days	0	100
(*c*) Incubator 85 Wet.													
30 July '10	×	—	—	B.S. Rag	4	85	dropped from ·80 to ·68				5	0	100
4 Aug. '10	×	—	—	,,	4	85	·74	—	—	—	—	4	Nil
10 ,,	—	×	—	,,	1	85	·74	—	—	—	—	0	100
9 Sept. '10	—	×	—	Bran	3	85	·70	—	—	—	—	0	100
22 ,,	—	—	×	B.S. Rag	12	85	·70	—	—	—	—	5	59
13 Oct. '10	×	—	—	Rat faeces	9	84	·72	—	—	—	12	0	100
5 Nov. '10	×	—	—	,,	14	84	·72	—	—	—	8	0	100
24 Dec. '10	—	—	×	B.S. Rag	16	84	·68	—	—	—	17	0	100
15 Mar. '11	×	—	—	Rat faeces crushed	26	84	·71	19	22	33	35	6	77
8 July '11	—	—	×	B.S. Rag	29	85·1	·83	9	14	23	—	22	24
8 ,,	—	—	×	Rat faeces crushed	28	85·1	·83	—	—	—	12	0	100
13 ,,	—	—	×	Flea faeces	28	85	·82	14	19	26	—	5	82
14 Nov. '11	—	—	×	Bran	22	85·2 75·0 92·4	·73 for 9 days ·69 for 7 days ·66 for remainder	—	—	—	17	—	100

24 Dec. '10	—	—	×	B.S. Rag	9	84·3		·60	—	—	—	No larvae seen after hatching	0	100
15 Mar. '11	×	—	—	Crushed Rat faeces	17	83·8		·59	—	—	—	2 days	0	100
28 Aug. '11	—	—	×	B.S. Rag	11	84·0		·64	—	—	—	No larvae seen after they were put into jar	0	100
						(e) Warm Cupboard.								
						Max.	Min.							
6 Aug. '10	×	—	—	B.S. Rag	3	69	68	about ·60	—	—	—	9	0	100
10 Oct. '10	—	—	×	,,	10	74	69	about ·60	—	—	—	None seen after emergence	0	100
22 ,,	×	—	—	Rat faeces	5	73	69	about ·60	—	—	—	,, ,, ,,	0	100
12 Nov. '10	×	—	—	B.S. Rag	1	59		·53	—	—	--	2	0	100
29 Mar. '11	×	—	—	Rat faeces crushed	26	61·5		·62	—	—	—	No larvae seen after placing in tube	0	100
						(f) Cellar.								
31 July '10	×	—	—	B.S. Rag	1	60	59	·93	—	34	—	—	1	Nil
4 Aug. '10	×	—	—	,,	4	60	59	·93	30	33	34	53	3	25
14 ,,	×	—	—	,,	1	59	58	·93	—	25	—	—	1	Nil
7 Oct. '10	—	—	×	,,	19	48	47	·93	75	87	104	146	8	—‖
22 ,,	×	—	—	Rat faeces	3	48	47	·93	—	---	—	114	0	100
4 April '11	×	—	—	,,	24	55·5	53·5	·92	69	99	114	—	2	91
25 June '11	—	—	×	,, crushed	26	62·5	61·4	·93	—	—	—	73	2	92
18 ,,	—	—	×	Flea faeces	32	60·4	59·1	·93	33	37	45	(32 cocoons)	31	3
25 ,,	—	—	×	B.S. Rag	27	61·1	59·9	·93	26	27	32	(27 ,,)	26	3%
21 Aug. '11	—	—	×	,,	14	Aug. 64·5	63·4	·94	22	27	36	(14 ,,)	13	7
21 ,,	—	—	×	Flea faeces	14	Sept. 60·6	59·5	·93	22	31	45	(11 ,,)	10	28
						(g) Beehive.								
10 April '11	×	—	—	Rat faeces crushed	19	70	39					12	0	100
						(h) Laboratory Cupboard.								
25 July '10	×	—	—	B.S. Rag	3	Approximate only until Nov. '10 60		·84	—	—	—	21	3	Nil
6 Aug. '10	—	×	—	,,	2				—	39	—	45¶	—	—
12 ,,	—	×	—	,,	4				33	34	39	—	4	Nil
18 ,,	—	×	—	Sweat soaked flannel	3				—	—	—	24	0	100
17 Sept. '10	—	—	×	Rat skin	4				—	—	—	62	0	100
27 ,,	—	—	×	B.S. Rag	4				—	—	—	141	0	100
15 Oct. '10	—	—	×	Rat faeces	5				—	—	—	24	0	100
19 ,,	—	×	—	B.S. Rag	5				—	—	—	17	0	100
26 ,,	×	—	—	Rat faeces	several				—	—	—	94	0	100
29 Mar. '11	×	—	—	,, crushed	26	56·3	45·8	·83	—	—	—	20	0	100
13 July '11	—	—	×	Flea faeces	28	72	64	·73	—	—	—	14	0	100
13 ,,	—	—	×	B.S. Rag	28	70	62	·74	—	—	—	Died off in less than 8 days	0	100
13 ,,	—	—	×	Rat faeces crushed	28	70	62	·74	—	—	—	,, ,, ,, 7 ,,	0	100

When two or more experiments bear the same date it may be taken that a batch of eggs or newly hatched larvae were divided.

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* Experiments given in Table XVI, up to and including those of 14 February, 1911, form a continuation of those made with ova set forth in Table II; data as to the corresponding cocoon stage will be found in Table XXVIII.

† The humidity was very low for a portion of the time, from the 21 to 24 Oct. 1910 it averaged ·61 only.

‡ The oatmeal developed swarms of mites. No sand was used.

§ 7 cocoons were opened and found to be empty, the larvae must have emerged again after spinning and died.

‖ 8 fleas bred. 1 cocoon, opened 8 May 1911, contained a resting larva which died. Remaining cocoons empty (false cocoons); mortality is really nil.

¶ 1 cocoon opened 1 Jan. 1911 contained a living larva.

TABLE XVII*. *Development of larvae,* C. fasciatus. *Influence of temperature and humidity upon larvae reared from egg; all eggs laid in incubator "75 Wet."*

Date	Tube	Box	Jar	Food	No. of larvae	Temperature	Method of moistening	Length of larval life to cocoon stage (in days)			Maximum number of days after hatching during which larvae were observed	No. of fleas reared	Mortality
								Min.	Aver.	Max.			
							(*a*) Incubator 75 Wet.						
1 Dec. '10	×	—	—	B.S. Rag	11	75	Water at start	—	—	—	22	0	100 %
6 ,,	×	—	—	,,	18	75	,,	—	—	—	17	0	100
8 ,,	×	—	—	,,	14	75	,,	—	—	—	No record	0	100
†28 ,,		Batch of eggs	×	,,	23	74	Urine at intervals	15	20	22	40	3	87
†28 ,,		divided	×	,,	21	74	Water ,,	15	22½	38	43	5	76
† 4 Mar. '11		Batch of 72 eggs	×	,,	13	74	Water 1 c.c. daily	—	10	—	14	1	92
† 4 ,,		divided	×	,,	25	74	Urine ,,	—	17	—	27 (only 2 cocoons found)	12	52
							(*b*) Incubator 75 Dry.						
8 Dec. '10	×	—	—	,,	12	74	Water at start	—	—	—	No larvae seen after emergence	0	100
17 ,,	×	—	—	,,	21	74	,,	—	—	—	,, ,, ,,	0	100
† 3 Jan. '11		Batch of 42 eggs	×	,,	12	76	Urine at intervals	—	—	—	,, ,, ,,	0	100
† 3 ,,		divided	×	,,	13	76	Water ,,	—	—	—	,, ,, ,,	0	100
†31 ,,		Batch of 61 eggs	×	,,	21	77	Urine daily	—	—	—	,, ,, ,,	0	100
†31 ,,		divided	×	,,	20	76·5	Water ,,	20	21	23	—	1	95
†28 Feb. '11		Batch of 60 eggs	×	,,	7	75·5	1 c.c. Urine daily	—	—	—	20	0	100
†28 ,,		divided	×	,,	17	75·5	1 c.c. Water ,,	—	—	—	11	0	100
†17 May '11	—	—	×	,,	20	75	0·5 c.c. Urine daily	—	—	—	28	0	100
†17 ,,	—	—	×	,,	20	75	0·5 c.c. Water ,,	—	—	—	1	0	100
6 ,,	—	—	×	,,	20	76	0·5 c.c. Urine ,,	—	—	—	No larvae seen after the 1st day	0	100
							(*c*) Incubator 85 Wet.						
1 Dec. '10	×	—	—	,,	12	84	Water at start	—	—	—	14	0	100
8 ,,	×	—	—	,,	7	84	,,	—	—	—	20	0	100
†30 ,,		Batch of 61 eggs	×	,,	24	84	Urine at intervals	15	15	17	29	5	79
†30 ,,		divided	×	,,	16	84	Water ,,	—	—	—	26	0	100
†24 Feb. '11		Batch of 72 eggs	×	,,	19	84	Urine 1 c.c. daily	12	14	16	17	2	90
†24 ,,		divided	×	,,	21	84·3	Water ,,	12	16	19	40	2	91

(*d*) Incubator 85 Dry.

†25 Nov. '10	×	Batch of 41 eggs divided		,,	13	84	Urine at intervals	—	—	—	No larvae seen after hatching		0	100
†25 ,,	×			,,	8	84	Water ,,	—	—	—	,, ,, ,,		0	100
1 Dec. '10	×	—	—	,,	11	84	Water at start	—	—	—	,, ,, ,,		0	100
6 ,,	×	—	—	,,	15	83	,,	—	—	—	,, ,, ,,		0	100
8 ,,	×	—	—	,,	9	84	,,	—	—	—	,, ,, ,,		0	100
17 ,,	×	—	—	,,	19	84	,,	—	—	—	,, ,, ,,		0	100
†30 ,,		Batch of 42 eggs divided	×	,,	20	84·9	Urine at intervals	—	—	—		21	0	100
†30 ,,			×	,,	15	85	Water ,,	—	—	—	No larvae seen after hatching		0	100
†27 Jan. '11		Batch of 39 eggs divided	×	,,	4	85	Urine daily	—	—	—	,, ,, ,,		0	100
†27 ,,			×	,,	9	85	Water ,,	—	—	—		15	0	100
†21 Feb. '11		Batch of 50 eggs divided	×	,,	hatching unrecorded	84	1 c.c. Urine daily	—	—	—		32	0	100
†21 ,,			×	,,		84	1 c.c. Water ,,	24	—	25		37	2	—
6 May '11	—	—	×	,,	20	84	·05 c.c. Urine daily	16	16	18		23	12	40
15 ,,	—	—	×	,,	20	84	·05 c.c. Water ,,	—	—	—		—	3	85

(*e*) Warm Cupboard.

9 Nov. '10	×	—	—	,,	5	60	Urine at intervals	—	—	—		18	0	100
† 3 Feb. '11		Batch of 64 eggs divided	×	,,	12	65	Urine daily	—	—	—		20	0	100
† 3 ,,			×	,,	19	63	Water ,,	—	95‡	—		—	1	94
† 8 Mar. '11		Batch of 70 eggs divided	×	,,	12	60·7	1 c.c. Urine daily	—	—	—		14	0	100
† 8 ,,			×	,,	16	61·2	1 c.c. Water ,,	28	30	37		37	10	38
5 May '11	—	—	×	,,	20	62·6	0·5 c.c. Urine daily	24	25	26	4 larvae died after spinning		3	85
6 ,,	—	—	×	,,	20	64·6	0·5 c.c. Water ,,	31	36	49	2 ,, ,, ,,		4	80

* The experiments given in Table XVII, up to and including those of 8 March 1911, form a continuation of those made with ova set forth in Table I; data as to the corresponding cocoon stage will be found in Table XXIX.

† against two experiments of the same date signifies that both were made with specimens from a single batch of ova or newly emerged larvae.

‡ One fully fed larva wandered about for 47 days before spinning cocoon.

(iii) Lagging Larvae. (See Table XXVI.) In addition to the ability of newly hatched flea larvae to exist for several days or weeks without food, some individuals of *C. fasciatus* were noticed to "lag" when they had attained their full growth, either finishing their larval feeding with extreme slowness or else waiting for considerable periods after they had finished feeding before spinning their cocoons.

It is possible that the larval period is not only lengthened by these practices in a few isolated instances, but that it is generally rendered more variable than would otherwise be the case.

When rearing from the egg, this phenomenon of "lagging" is not very noticeable owing to the varying speed attained in development by different individuals, but it becomes quite evident when a number of full sized larvae are taken from the cages. This was done between the end of January and the middle of March 1911 in order to obtain a number of newly emerged fleas to stock a new cage. About 120 larvae of *C. fasciatus* were put into a jar in incubator 75 Wet (temperature 74°F., humidity ·74) on the 27th January, 1911. Several had spun their cocoons by the following day; many fleas emerged and were added to the new cage. On the 4th March it was decided to add a fresh batch of larvae from the cages to the same jar. When it was opened for this purpose some of the larvae put in on the 27th January were discovered to be still active after a period of 36 days, numbers of their fellows having in the meantime emerged as fleas. After putting in the second batch on the 4th of March, active larvae were observed in this jar until the 5th of May; allowing that these were all members of the second batch, it would show "lagging" on the part of some of them for varying periods up to 62 days.

A similar instance occurred with another batch of 100 larvae put into the same incubator on the 17th March; most of these spun at once, but stragglers were seen at intervals, the last being observed on the 19th April, over a month later.

A third series of 100 larvae, put into incubator 75 Wet on the 22nd March (temperature 75° F., humidity ·74), showed the same phenomenon, the last active larva being seen on the 1st May, 49 days later. Advantage was taken of one of the "complex transference" cocoon experiments to follow the matter up with a little more detail (see Table XXVI), from which it appears that these lagging larvae are not simply pining individuals that subsequently die, for, as will be seen, most of them eventually spun cocoons and emerged.

TABLE XVIII. *Development of larvae,* C. fasciatus *reared from the egg; eggs all laid in incubator "75 Wet."*

(*a*) Influence of varied situation (temperature and humidity); nature of the food supply being maintained constant. Eggs taken from the same batch.

Date on which eggs were laid or larvae placed under test conditions	Place	Receptacle	Food	No. of larvae	Temp.	Humidity	Lengths of larval life to cocoon stage (in days) Min.	Aver.	Max.	Max. number of days after hatching during which larvae were observed	No. of fleas reared	Mortality
19 Oct. '10	Incubator 75 Wet	Box	B.S. Rag	9	75	Av. ·69 *	—	—	—	—	0	100 %
	Lab. cupboard	Box	,,	5	60	·84	—	—	—	17	0	100
22 Oct. '10	Warm cupboard	Tube	Rat faeces	5	max. min. 69 64	Unrecorded	—	—	—	No larvae seen after hatching	0	100
	Cellar	,,	,,	3	48 47	·91 to ·93	—	—	—	114	0	100
1 Dec. '10	Incubator 85 Wet	,,	B.S. Rag	12	84	Moistened	—	—	—	14	0	100
	,, 85 Dry	,,	,,	11	84	,,	—	—	—	No larvae seen after hatching	0	100
6 Dec. '10	,, 75 Wet	,,	,,	18	75	,,	—	—	—	No record	0	100
	,, 85 Dry	,,	,,	15	83	,,	—	—	—	No larvae seen after hatching	0	100
8 Dec. '10	,, 75 Dry	,,	,,	12	74	,,	—	—	—	,, ,, ,,	0	100
	,, 85 Dry	,,	,,	9	84	,,	—	—	—	,, ,, ,,	0	100
14 Mar. '11 15 Mar. '11	,, 75 Wet	,,	Rat faeces crushed	26	75	·80	20	28	45	59	5	87
	,, 85 Wet	,,	,,	26	84	·71	19	22	33	35	6	77
	,, 85 Dry	,,	,,	17	83·8	·59	—	—	—	2	0	100
	,, 75 Dry	,,	,,	20	74·5	·49	—	—	—	No larvae seen after placing in tube	0	100
29 Mar. '11	Warm cupboard	,,	,,	26	61·5	·62	—	—	—	,, ,, ,,	0	100
	Lab. cupboard	,,	,,	26	max. min. 53·3 45·8	·83	—	—	—	20	0	100

(*b*) Influence of varied food supply under constant conditions of temperature and humidity in case of eggs or newly hatched larvae taken from the same batch.

Date on which eggs were laid or larvae placed under test conditions	Place	Receptacle	Food	No. of larvae	Temp.	Humidity	Min.	Aver.	Max.	Max. number of days after hatching during which larvae were observed	No. of fleas reared	Mortality
23 May '11	Incubator 75 Wet	Jar	Flea faeces	28	75·8	·84	15	18	20	—	20	29
	,, ,,	,,	Rat faeces	28	75·8	·84	15	17	20	34	0	100
	,, ,,	,,	B.S. Rag	28	75·8	·84	15	17	22	—	20	29
25 June '11	Cellar	,,	Rat faeces crushed	26	max. min. 62·5 61·4	·93	—	—	—	73	2	92
	,,	,,	B.S. Rag	27	61·1 59·9	·93	26	27	32	—	26	3
21 Aug. '11	,,	,,	,,	14	Aug. 64·5 63·4 Sept. 60·6 59·5	·94 ·93	22	27	36	—	13	7
	,,	,,	Flea faeces	14	,, ,,	,,	22	31	45	—	10	28
13 July '11	Lab. cupboard	,,	,,	28	72 64	·73	—	—	—	14	0	100
	,,	,,	B.S. Rag	28	70 62	·74	—	—	—	Died off in less than 8 days	0	100
	,,	,,	Rat faeces crushed	28	70 62	·74	—	—	—	,, ,, 7 ,,	0	100

* Humidity ran very low for a portion of the time, from 21—24 Oct. it averaged only ·61.

TABLE XIX. *Development of larvae,* X. cheopis. *Influence of temperature and humidity upon larvae taken from the breeding cages when half to full grown.*

Date on which larvae were placed under test conditions	No. of larvae	Receptacle	Place	Food	Temp.	Humidity	No. of cocoons found	No. of fleas reared	Mortality	No. of days start to emergence	No. of days in cocoon	Remarks
30 Nov. '11	22	Card jar	Incubator 75 Wet	B.S. Rag	75·8	·65	21	22	nil	1—16 6—19 3—22 2—24 5—26 1—28 2—32 2—34	—	
30 Nov. '11	22	,,	Incubator 75 Dry	,,	74·7	·51	—	—	100 %	—	—	No larvae seen alive after the start
30 Nov. '11	22	,,	Incubator 92 Wet	,,	92·4	·66	15	13	41	2—13 6—16 2—19 3—22	6—11 5—14 2—17	2 cocoons contained dried up fleas, remainder false cocoons
30 Nov. '11	22	,,	Incubator 92 Dry	,,	92·8	·57	13	10	54	3—13 5—16 2—19	6—11 4—14	2 cocoons contained dried up fleas, 1 a dried up larva, remainder false cocoons
5 Dec. '11	22	,,	Cellar	,,	48·7 47·4	·92	1	—	100	—	—	
5 Dec. '11	22	,,	Lab. cupboard	,,	54·2 46·0	·84	1	—	at least 95	—	—	Cocoon opened 12 Apr. '12, fouud to contain living section of larva which subsequently died, 129 days
2 Apr. '12	22	,,	Cellar	,,	50·3 49·1	·93	1	—	100	—	—	
2 Apr. '12	22	,,	Lab. cupboard	,,	60·6 50·4	·83	1	—	100	—	—	Cocoon opened, contained dead pupa
2 Apr. '12	22	,,	Beehive	,,	64·1 37·3	—	—	—	100	—	—	Larvae dead by 12 Apr.
2 Apr. '12	22	,,	Warm cupboard	,,	61	·61	—	—	100	—	—	Larvae dead in 2 days
2 Apr. '12	22	,,	Incubator 75 Wet	,,	75·8	·79	21	19	13	1—18 3—21 9—25 2—27 3—35 1—38	1—13 1—14 10—17 4—19 2—21 1—20	
2 Apr. '12	22	,,	Incubator 75 Dry	,,	74·4	·56	—	—	100	—	—	Larvae dead in 2 days
2 Apr. '12	22	,,	Incubator 92 Wet	,,	93·1	·69	17	10	54	1—11 3—16 3—21 2—25 1—27	1— 9 3—14 1—15 2—16 1—18 2—19	
2 Apr. '12	22	,,	Incubator 92 Dry	,,	93·7	·61	16	4	81	2—18 1—21 1—25	2—16 1—19 1—23	
9 Sept. '12	22	,,	Incubator 75 Dry	,,	75·0	·52	—	—	100	—	—	No larvae seen alive after the 2nd day
9 Sept. '12	22	,,	Incubator 93 Dry	,,	92·0	·53	—	—	100	—	—	No larvae seen alive after

TABLE XX*. *Development of larvae*, X. cheopis. *Influence of temperature, humidity and food supply reared from the egg; all eggs laid in incubator "75 Wet."*

Date on which eggs were laid	Tube	Box	Jar	Food	Number	Temperature	Humidity	Length of larval life to cocoon stage (in days) Min.	Average	Max.	Max. number of days after hatching during which active larvae were observed	Number of Fleas	Mortality
							Cellar.						
6 June '11	×	—	—	B.S. Rag	6	max. min. June 58·1 56·7 July 61·6 60·4 Aug. 64·5 63·4 Sept. 60·6 59·5 Oct. 56·3 54·8 Nov. 50·7 48·9 Dec. 48·7 47·4	·93 ·93 ·94 ·93 .92 ·91 ·92	58	71	84	(2 cocoons)	1	83 %
3 July '11	—	—	×	Flea faeces	14			44	46	65	(13 cocoons)	8	42
3 July '11	—	—	×	Rat faeces crushed	14			37	42	44	(14 cocoons)	11	21
21 Sept. '11	—	—	×	B.S. Rag	22						74 days No larvae seen after 4 Dec.	—	100
							Incubator 85 Wet.						
11 Aug. '11	—	—	×	B.S. Rag	13	84·4	·80	14	16	22	—	12	8
11 Aug. '11	—	—	×	Flea faeces	11	84·3	·80	—	14	—	—	7	36
4 Sept. '11	—	—	×	B.S. Rag	22	84·5	·74	12	13	16	(22 cocoons) —	20	9
							Incubator 75 Wet.						
4 Sept. '11	—	—	×	B.S. Rag	22	74·8	·76	14	19	21	(21 cocoons)	21	5
							Incubator 75 Dry.						
28 Aug. '11	—	—	×	B.S. Rag	11	74	·61	—	—	—	No larvae seen after 1st day	—	—
							Incubator 85 Dry.						
28 Aug. '11	—	—	×	B.S. Rag	11	84	·60	—	—	—	No larvae seen after 3rd day	—	—
							Warm Cupboard.						
4 Sept. '11	—	—	×	B.S. Rag	22	68·1	·65	—	—	—	No larvae seen after 7th day	—	100
							Laboratory Cupboard.						
4 Sept. '11	—	—	×	B.S. Rag	22	max. min. Sept. 65·7 55·7 Oct. 59·0 50·9 Nov. 54·9 46·1 Dec. 52·7 44·3	·77 ·84 ·85 ·88	(Lowest reading 40 on 22 Nov. and three times in Dec. before the 11th)			98 days No larvae seen after 11 Dec.	—	100
							Beehive.						
20 Sept. '11	—	—	×	B.S. Rag	22	Sept. 75·3 48·0 Oct. 61·9 41·3		(Lowest reading 28°F. on 26 Oct. '11, twice below 40 during Sep.)			37 days No larvae seen after 27 Oct.	—	100
							Incubator 85 Wet.						
14 Nov. '11	—	—	×	Bran	22	10 days at 85·2 7 ,, 75·0	·73 ·69			—	15 days	2	90
							Incubator 75 Wet.						
22 Nov. '11	—	—	×	Bran	22	75·0	·69				20 days	18	18

* The continuation of these experiments through the cocoon-stage will be found in Table XXXIV.

TABLE XXI*. *Development of larvae,* P. irritans. *Influence of temperature, humidity and food supply upon larvae reared from the egg.*

Date on which eggs were laid	Tube	Box	Jar	Food	No. of larvae	Temp.	Humidity	Length of larval life to cocoon stage (in days) Min.	Av.	Max.	Max. number of days after hatching during which active larvae were observed	No. of fleas reared	Mortality
(*a*) Incubator 75 Wet.													
13 July '10	×	—	—	Rat faeces	7 eggs, no record of hatching	75	Unrecorded	15	16	18	17	2	—
19 ,,	×	—	—	Dead flies†	4	75	,,	12	15	17	17	2	50 %
11 Aug. '10	×	—	—	B.S. Rag	7	75	·66	22	23	26	—	4	43
1 Oct. '10	—	—	×	,,	5	74·3	·72‡	—	12	—	13	1	80
10 ,,	—	—	×	,,	45	74·3	·78‡	—	—	—	6	0	100
14 ,,	—	×	—	Bran	15	74·3	·74‡	—	—	—	No larvae seen after hatching	0	100
15 Feb. '11	×	a batch of 69 eggs divided		Oatmeal§	17	74·4	·76	—	—	—	23	0	100
15 ,,	×			Oatmeal and flea faeces§	6	74·4	·76	—	—	—	20	0	100
15 ,,	×			Oatmeal and B.S. Rag§	12	74·4	·76	—	—	—	23	1	92
27 Mar. '11	×	—	—	Rat faeces crushed	13	75	·80	14	19	23	—	10	23
24 Apr. '11	×	—	—	Powdered dry blood, no sand	7	74·7	·83	—	—	—	18	0	100
9 June '11	—	—	×	B.S. Rag	24	75·7	·85	10	15	26	—	21	13
9 ,,	—	—	×	Flea faeces	24	75·8	·85	15	21	46	—	5	79
18 Oct. '11	—	—	×	B.S. Rag	22	74·4	·73	13	16	23	—	16	27
(*b*) Incubator 75 Dry.													
4 June '11	—	—	×	B.S. Rag	20	78	·63	—	—	—	No larvae seen after start	0	100
9 June '11	—	—	×	Flea faeces	24	75	·53	—	—	—	,, ,,	0	100
22 Aug. '11	—	—	×	B.S. Rag	26	75·7	·59	—	—	—	3 larvae seen on 2nd day, none afterwards	0	100
(*c*) Incubator 85 Wet.													
24 July '10	×	—	—	B.S. Rag	13 eggs, no record of hatching	about 85	Doubtful record, varies from ·80 to ·68	—	12	—	—	1	—
6 Aug. '10	×	—	—	,,	12 eggs	85	·74	—	9	—	—	1	—
26 Sept. '10	—	—	×	Flea faeces	23	85	·70	9	15	22	27	4	83
14 Oct. '10	—	×	—	Bran	7	84	·72	No cocoons found			8	2	72
29 Mar. '11	×	—	—	Rat faeces crushed	15	84	·71	9	12	15	—	8	47
6 June '11	—	—	×	B.S. Rag	26	84	·80	8	14	24	—	16	38
7 ,, '11	—	—	×	Flea faeces	20	84	·80	12	14	17	—	8	60
14 Nov. '11	—	—	×	Bran	22	85·2	·73	—	—	—	15	1	95
5 Jan. '12	—	—	×	B.S. Rag	24	92·6	·66	11	12	15	—	1	95
22 Mar. '12	—	—	×	,,	22	92·3	·67	10	11	12	—	9	59
(*d*) Incubator 85 Dry.													
6 June '11	—	—	×	B S. Rag	26	85	·61	—	—	—	No larvae seen after start	0	100
7 ,,	—	—	×	Flea faeces	20	85	·50	—	—	—	,, ,,	0	100
22 Aug. '11	—	—	×	B.S. Rag	26	83·8	·63	—	—	—	,, ,,	0	100

						max.	min.							
22 Sept. '10	×	—	—	Flea faeces	3	74	61	Between ·50 & ·60	—	—	—	No larvae seen after emergence	0	100
6 Oct. '10	—	—	×	B.S. Rag	23 or more	76	65	,, ,,	—	—	—	,, ,, ,,	0	100
18 ,,	—	×	—	Bran	4	74	70	,, ,,	—	—	—	,, ,, ,,	0	100
12 June '11	—	—	×	Flea faeces	20	Dry 65·0		·59	—	—	—	No larvae seen after start	0	100
6 ,,	—	—	×	B.S. Rag	26	73·0		·62	—	—	—	,, ,,	0	100

· (*f*) Cellar.

						max.	min.							
6 Oct. '10	—	—	×	B.S. Rag	9	48	47	·91—·93	76	106	137	196	2 cocoons‖	100
14 ,,	—	×	—	Bran	11	48	47	·91—·93	122	162	202	212	2	82
3 June '11	—	—	×	B.S. Rag	24	June 58·1	56·7	·93	48	54	73	—	16	33
12 ,,	—	—	×	Flea faeces	28	July 61·6	60·4	·93	39	50	78	92	16	42
						Aug. 64·5	63·4	·94						
						Sept. 60·3	59·5	·93						
11 Aug. '11	—	—	×	Flea faeces	35	Aug. 64·5	63·4	·94	26	37	55	—	23	34
11 ,,	—	—	×	B.S. Rag	35	Sept. 60·6	59·5	·93	32	42	65	1 flea took 272 days from start	17	51
						Oct. 56·3	54·8	·92						
						Nov. 50·7	48·9	·91						
						Dec. 48·7	47·4	·92						
						Jan. 47·2	45·9	·92						
						Feb. 45·8	44·6	·92						
						Mar. 49·1	48·1	·93						
						Apr. 50·3	49·1	·93						
						May 54·2	53·2	·93						

(*g*) Laboratory cupboard.

13 July '10	×	—	—	Rat faeces	2	60¶		·84¶	—	37	—	—	1	50
29 ,,	—	×	—	Dust from sleeping bag	4 eggs, no record of hatching				—	—	--	26	2	—
29 ,,	—	×	--	Old carpet	2				—	—	—	32	0	100
1 Aug. '10	×	—	—	Flea faeces	1				—	12	--	—	1	Nil
11 ,,	×	—	—	B.S. Rag	9				35	39	44	44	6**	34
14 ,,	—	×	—	Dust from sleeping bag and a few spots of flea faeces on gauze	5				17	32	39	No cocoons found	1	80
20 ,,	—	×	—	Flea faeces	10				34	50	62	—	5	50
1 Oct. '10	—	—	×	B.S. Rag	17				65	85	100	—	11	36
10 ,,	—	×	—	Bran	8				81	84	87	223	1	87
						max.	min.							
3 June '11	—	—	×	B.S. Rag	24	68·4	60·1	·77	39	47	54	—	7	71
12 ,,	—	—	×	Flea faeces	28	69·0	61·1	·77	30	39	58	—	13	54

(*h*) Beehive.

6 ,,	—	—	×	B.S. Rag	26	79	56	—	—	—	—	No larvae seen after start	0	100
12 ,,	—	—	×	Flea faeces	20	69·5	50·5	—	—	—	—	2	0	100

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* Experiments given in Table XXI up to and including those of 15 February 1911, form a continuation of those made with ova set forth in Table V; data as to the corresponding cocoon stage will be found in Table XXXVI.

† *Musca domestica.*

‡ Humidity ran very low for a portion of the time, from 21—24 October it averaged ·61 only.

§ Oatmeal developed swarms of mites.

‖ Larvae came out, wandered about and failed to pupate.

¶ Temperature and humidity approximate only to Nov. 1910, see actual records after this date in relation to extended larval life.

** 1 cocoon opened 1 Jan. 1911 contained living flea.

TABLE XXII. *Development of larvae,* P. irritans *reared from the egg. Influence of varied situation (temperature and humidity), nature of food supply being kept constant; in each experiment all eggs taken from the same batch.*

Date (*a*) on which eggs were laid	Place	Receptacle	Food	Number of larvae	Temperature	Humidity	Length of life to cocoon stage (in days)			Maximum number of days after hatching during which larvae were observed	Number of fleas reared	Mortality
							Min.	Aver.	Max.			
14 Oct. '10 46 eggs divided	Incubator 75 Wet	Box	Bran	15	Dry 74·3	·74 from 21 May ·61 only	—	—	—	—	0	100 %
	Cellar	,,	,,	11	max. min. 48 47	·91 to ·93	122	162	202	212	2	82
11 Aug. '10 27 eggs divided	Incubator 75 Wet	Tube	B.S. Rag	7	Dry 75	·66	22	23	26	—	4	43
	Lab. Cupboard	,,	,,	9	approx. 60	·84	35	39	44	44	6	34
(*b*) on which larvae were placed under test conditions												
6 June '11	Incubator 85 Dry	Jar	,,	26	85	·61	—	—	—	No larvae seen after start	0	100
	,, 85 Wet	,,	,,	26	84·1	·78	8	14	24	—	16 (2 cocoons empty)	38
3 June '11	Cellar	,,	,,	24	max. min. 60·8 59·5	·93	48	54	73	—	16	42
	Lab. Cupboard	,,	,,	24	68·4 60·1	·77	39	47	54	—	7	71
6 June '11	Warm Cupboard	,,	,,	26	73	·62	—	—	—	No larvae seen after start	0	100
	Beehive	,,	,,	26	max. min. 79 56	—	—	—	—	,, ,, ,,	0	100
7 June '11	Incubator 85 Wet	,,	Flea faeces	20	84	·79	12	14	17	—	8 (1 cocoon opened empty)	60
	,, 85 Dry	,,	,,	20	85	·49	—	—	—	No larvae seen after start	0	100
9 June '11	,, 75 Wet	,,	B.S. Rag	24	75·7	·85	10	15	26	—	21	13
	,, 75 Wet	,,	Flea faeces	24	75·8	·85	15	21	46	—	5	79
	,, 75 Dry	,,	,,	24	75	·55	—	—	—	No larvae seen after start	0	100
12 June '11	Cellar	,,	,,	28	—	—	—	—	—	—	16	42*
	Lab. Cupboard	,,	,,	28	max. min. 69·0 61·1	·77	30	39	58	—	13	54
	Warm Cupboard	,,	,,	20	65	·59	—	—	—	No larvae seen after start	0	100
	Beehive	,,	,,	20	max. min. 68·6 46·3	—	—	—	—	2	0	100

* For conditions of temperature and humidity see record in Table XXI.

TABLE XXIII. *Development of larvae* C. gallinae *reared from the egg; eggs obtained from adults kept in incubator "75 Wet" and fed daily on human blood.*

Date	Receptacle	Food	Place	Number	Temp.	Humidity	Length of larval life to cocoon stage (in days) Min.	Aver.	Max.	Mortality	Duration of cocoon period	No. of fleas reared
24 March '11	Tube	Dust from nest and flea faeces	Incubator 75 Wet	16	Mar. 74·3 April 75·0 May 74·9	·76 ·78 ·85	13	14	21	Nil	1 in 6 days 4 in 9 days 2 in 11 days 1 in 12 days 1 in 13 days 1 in 14 days 1 in 16 days	11 5 larvae were taken as specimens

TABLE XXIV. *Development of larvae* Ct. canis. *Influence of temperature and humidity; eggs obtained from a dog's bed and hatched in incubator "75 Wet."*

Date	Tube	Box	Jar	Food	Number	Temperature	Humidity	Length of larval life to cocoon stage (in days) Min.	Aver.	Max.	Max. number of days after hatching during which active larvae were observed	No. of fleas	Mortality
							Incubator 75 Wet.						
9 May '12	—	—	×	B.S. Rag	22	75·6	·86	12	13	19	—	8	63 %
							Incubator 93 Wet.						
,,	—	—	×	,,	22	95·1	·75	—	11	—	—	0	100
							Incubator 93 Dry.						
,,	—	—	×	,,	22	93·3	·58	—	—	—	5 days	0	100
							Incubator 75 Dry.						
,,	—	—	×	,,	22	75·0	·66	—	—	—	1 day	0	100
							Cellar.						
,,	—	—	×	,,	22	*—	—	49	61	142	52 days	2	91
							Laboratory Cupboard.						
,,	—	—	×	,,	22	*—	—	35	39	42†	38 days	13	40
							Beehive.						
,,	—	—	×	,,	22	max. 74·3 min. 54·3	—	—	—	—	3 days	0	100
							Ice Chest.						
,,	—	—	×	,,	22	May 39·3 June 40·9 July 43·6	·95 ·99 ·95	—	—	—	75 ,,	0	100

* See page 461 for records of temperature and humidity, May to August 1912.
† 2 fleas emerged 15 July '12; 2 living fleas were taken out of cocoon on 6 Sept.; 9 living fleas were taken out of cocoon on 1 Oct. 1912.

TABLE XXV*. *Development of larvae, comparing influence of temperature and humidity upon larvae of the three species* X. cheopis, P. irritans, *and* C. fasciatus.

Date 1911	Receptacle	Species	Place	Food	Number	Temperature			Humidity	Length of larval life to cocoon stage (in days) Min.	Aver.	Max.	Max. number of days after hatching during which active larvae were observed	No. of fleas	Mortality
28 Aug.	Jar	*X. cheopis*	Incubator 85 Dry	B.S. Rag	11	84			·60	—	—	—	No larvae after 3rd day	—	100 %
29 ,,	,,	*P. irritans*	,, ,,	,,	11	84			·60	—	—	—	,, ,, 2nd ,,	—	100
28 ,,	,,	*C. fasciatus*	,, ,,	,,	11	84			·60	—	—	—	,, ,, start	—	100
28 ,,	,,	*X. cheopis*	Incubator 75 Dry	,,	11	74			·61	—	—	—	,, ,, 1st day	—	100
29 ,,	,,	*P. irritans*	,, ,,	,,	11	75			·58	—	—	—	,, ,, ,,	—	100
28 ,,	,,	*C. fasciatus*	,, ,,	,,	11	74·6			·59	—	—	—	,, ,, 3rd day	—	100
4 Sept.	,,	*X. cheopis*	Incubator 85 Wet	,,	22	84·5			·74	12	13	16	—	20	9
4 ,,	,,	*P. irritans*	,, ,,	,,	22	84·7			·77	10	12	19	—	19	13
11 ,,	,,	*C. fasciatus*	,, ,,	,,	21	84·9			·77	9	13	19	—	14	33
4 ,,	,,	*X. cheopis*	Incubator 75 Wet	,,	22	74·8			·76	14	19	21	—	21	5
4 ,,	,,	*P. irritans*	,, ,,	,,	22	74·9			·75	12	18	30	—	17	22
14 Oct.	,,	*C. fasciatus*	,, ,,	,,	22	74·4			·71	13	20	31	—	20	9
4 Sept.	,,	*X. cheopis*	Warm Cupboard	,,	22	68·1			·65	—	—	—	No larvae after 7th day	—	—
4 ,,	,,	*P. irritans*	,, ,,	,,	22	69			·71	—	—	—	,, ,, 2nd ,,	—	—
6 ,,	,,	*C. fasciatus*	,, ,,	,,	22	67			·66	—	—	—	,, ,, ,,	—	—
							max.	min.							
4 ,,	,,	*X. cheopis*	Lab. Cupboard	,,	22	Sept.	65·7	55·7	·77	—	—	—	97	—	100
5 ,,	,,	*P. irritans*	,, ,,	,,	22	Oct.	59·0	50·9	·84	45	62	83	192	5	77
5 ,,	,,	*C. fasciatus*	,, ,,	,,	22	Nov.	54·9	46·1	·85	56	62	67	(4 cocoons)†	—	81
						Dec.	52·7	44·3	·88						
20 ,,	,,	‡*X. cheopis*	Beehive	,,	22	Sept.	75·3	48·0	—	—	—	—	37	0	100
19 ,,	,,	*P. irritans*	,,	,,	22	Oct.	61·9	41·3	—	—	—	—	188	—	100
19 ,,	,,	*C. fasciatus*	,,	,,	22					83	88	100	(7 cocoons)§	5	68
21 ,,	,,	‖*X. cheopis*	Cellar	,,	22	Sept.	60·6	59·5	·93	—	—	—	74	—	100
25 ,,	,,	*P. irritans*	,,	,,	22	Oct.	56·3	54·8	·92	37	52	63	184 (6 cocoons)¶	4	81
25 ,,	,,	*C. fasciatus*	,,	,,	22	Nov.	50·7	48·9	·91	37	48	70	(18 cocoons)**	9	36
						Dec.	48·7	47·4	·92						

* In compiling this table, the records for *X. cheopis* are all taken from Table XX and two records for *C. fasciatus* (those in incubators 85 Dry and 75 Dry) from Table XVI. The remaining figures given for *C. fasciatus* and those for *P. irritans* are the results of special experiments not quoted elsewhere.

† 3 July, 1 cocoon opened contained resting larva; 6 Sept., 2 cocoons opened contained resting larvae, 367 days; 11 Sept., 1 cocoon opened contained resting larva, 372 days.

‡ No larvae seen subsequently to 27 Oct. 1911. Lowest reading 28° F. on 26 Oct. 1911. Thermometer was on two occasions below 40° F. during Sept.

§ Last flea emerged 15 June 1912; 4 July, a cocoon opened contained resting larva which pupated on 3 Sept. 1912, 350 days; 11 Sept. 1912, 1 cocoon opened contained a living pupa, 358 days.

‖ No larvae seen subsequently to 4 Dec. 1911.

¶ Last flea emerged 16 May 1912.

** 6 fleas emerged up to 6 Sept. 1912; 3 fleas emerged 11 Sept. 1912 upon the cocoons being disturbed; cocoons opened 11 Sept. 1912, 5 living pupae, 2 dead pupae, 2 empty.

TABLE XXVI. *Lagging. Full grown larvae,* C. fasciatus *taken from the cages.*

Date	Number	Place	Receptacle	Temperature	Humidity	Active larvae observed	Cocoons found
11 April '11	26	Incubator 75 Wet	Tube	74·7	·87	Several 5 May = 24 days	12 in 2 days
						,, 8 ,, = 27 ,,	3 in 4 ,,
						,, 10 ,, = 29 ,,	1 in 5 ,,
						Two 12 ,, = 31 ,,	1 in 31 ,,
							2 in 34 ,,
				max. min.			
,,	26	Beehive	Tube	65 39	—	One 22 ,, = 41 ,,	Only one cocooon found within 8 days
26 April '11	Several	Incubator 75 Wet	Tube	74·5	·83	Several 8 ,, = 12 ,,	No record. Pupae taken out of cocoons for specimens
						,, 10 ,, = 14 ,,	
						,, 12 ,, = 16 ,,	
						,, 15 ,, = 19 ,,	
				max. min.			
11 April '11	26	Cellar	Tube	April 48·5 46·6	·91	,, 18 ,, = 37 ,,	1 in 2 days
				May 53·9 52·6	·92	One 8 June = 58 ,,	3 in 6 ,,
				June 58·1 56·7	·93	,, 15 ,, = 65 ,,	9 in 11 ,,
							3 in 14 ,,
							1 in 16 ,,
							2 in 42 ,,
							5 in 46 ,,
							1 in 58 ,,
							1 in 76 ,,

3. COCOONS (Tables XXVIII to XLIV).

i. *Influence of temperature, humidity and previous history upon duration of this period.*

In the life history of the flea the cocoon stage is the period in which it is most independent of external conditions of temperature, humidity, etc. and in least danger from the attacks of enemies. It is, therefore, not surprising to find that there tends to be an accumulation of individuals in this stage, from which the active adult population is recruited when suitable conditions offer. In the cocoon period, as in other stages, external conditions and individual idiosyncrasy combine to produce an inextricably interwoven condition of affairs. An attempt was made to disentangle the several strands by means of three different series of experiments with each species:

a. "Continuous" experiments in direct continuity with previous egg and larval experiments:—The cocoons were kept until the emergence of fleas in the same situations as the eggs were laid and hatched and the larvae reared. In the case of *C. fasciatus* these experiments are to be found in Tables XXVIII and XXIX, the corresponding observations on larval and egg stages being given in Tables XVI, XVII and I and II respectively. The cocoon observations for *X. cheopis* set forth in Table XXXIV correspond to Table XX (larvae) and those for *P. irritans* in Table XXXVI to Tables XXI (larvae) and V (ova). In this series the observations upon cocoons are necessarily more limited than the corresponding ones dealing with both eggs and larvae, for in many cases the drastic conditions to which the last-named were subjected left no survivors to undergo a cocoon stage. In nature it is usual for larvae to develop and to spin cocoons before the onset of climatic conditions, which would be fatal to them in the free state.

b. "Simple transference" experiments in which cocoons were obtained as follows:—In case of *C. fasciatus* and *X. cheopis* full-grown larvae were taken from the breeding cages and placed in card jars with sand and B.S. rag. The jars were all put into incubator 75 Wet and the larvae allowed to spin. The cocoons as found were transferred to glass bottomed boxes and these were buried in sand and placed in the different situations investigated. Table XXXI deals with *C. fasciatus* and Table XXXV with *X. cheopis*. In Table XXXVIII are given the results of a series of experiments with *P. irritans*, arranged to correspond as nearly as possible with those of the other two species. In this instance, however, the larvae were reared until full grown in incubator 75 Wet. In this series of experiments the influence of varied conditions prior to spinning is eliminated as far as possible, and the results afford a comparison, uncomplicated by other circumstances, of the influence of varied external conditions upon the cocoon stage itself.

c. "Complex transference experiments" in which cocoons were maintained under conditions which were the opposite of those under which they were spun. For example, a batch of larvae taken from the breeding cages (in case of rat fleas) or reared in incubator 75 Wet (in the case of *P. irritans*) was placed to spin in incubator 85 Dry, after which the cocoons were transferred to the cellar. In other cases, cocoons spun in the cellar were maintained till emergence of the adult in incubator 85 Dry, and so on. In the tables dealing with this third series (XXXII in case of *C. fasciatus* and XXXIX in case of *P. irritans*) the number of days recorded as being passed in the cocoon stage is approximate[1] only, as the cocoons were not all changed into their new quarters on the same day.

In some of the experiments of the "continuous" series during 1910 and the early months of 1911 discrepancies will be noted between the numbers of cocoons investigated and the fleas recovered. These differences came about owing to the habit the flea larva possesses of sometimes forsaking its cocoon and wandering away to seek a more suitable situation. The deserted cocoons do not differ in any outward respect from full ones and constitute a source of possible error in estimating the mortality at the cocoon stage. So soon as this habit was discovered, deserted cocoons were subjected to careful examination at the close of an experiment, in order to determine whether they were really empty or contained the cast larval skin. The mortality in all but the earliest experiments is based upon the number of cocoons in which actual remains of dead larvae, pupae or fleas were found in the cocoon. In a few of the 1910 experiments, however, made before this routine examination had been instituted, the calculated percentage of failures in the cocoon stage may be too high owing to the inclusion of deserted cocoons. In the "continuous" series the error will consist in attributing too great mortality to the cocoon stage and too little to the larval stage.

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[1] For instance, if two cocoons were transferred to the test situation on 1st January and two more on the 10th January, and one flea emerged on February 1st, it would be reckoned to have spent 30 days in the cocoon.

In the second and later series of experiments there is possibly an erroneous estimate of the number of cocoons experimented with. On the whole it was considered better to underestimate the mortality rather than overestimate it and therefore, in making the calculation, empty cocoons that retained no trace of a tenant were disregarded. They are referred to in the tables as "false" cocoons, and in some cases, where the numbers seemed unduly large, the percentage of mortality has been put down as doubtful. This caution is thought necessary because in hot and dry situations there is a possibility that the larva may leave its cocoon and failing to find a more suitable situation may break up into unrecognizable fragments among the sand and other debris from the cocoons.

Further sources of error in obtaining cocoon statistics are the possibility of two larvae spinning their cocoons against one another and the rare chance of a double cocoon being formed. In only one or two instances, however, has the recorded number of cocoons been exceeded by the joint number of fleas emerging and of remnants found. There is still the possibility that in these cases a wrong count was made.

P. irritans[1]. The results of the "continuous" series of experiments with this species are given in Tables XXXVI and XXXVII. In the "simple transference" (Table XXXVIII) and "complex transference" experiments (Table XXXIX) the larvae used were reared until full grown in incubator 75 Wet.

For full comprehension of the degree of variability displayed by the cocoons of this species in their reaction to external conditions, it is necessary to study in detail the four Tables referred to above, but the following paragraphs may be found useful in giving a general review of the results obtained.

The influence of high temperature in shortening the duration of the cocoon stage may be seen in the following summary compiled from Table XXXIII.

Experiments, in which the average humidity was between ·7 and ·9.

Temperatures	Average humidity	Number of cocoons	Average duration of cocoon stage
83·9—85·0	from ·7 to ·9	77	11·9
74·4—76·1		78	17·2

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[1] The experiments with *P. irritans* are discussed first because with this flea the nature of the reaction to temperature and humidity appears to be less complex than in the case of *C. fasciatus*.

When the range of temperature was at a lower level, the divergence in cocoon period corresponding to difference of temperature was much greater: compare experiments in incubator 75 Dry, 15th April, 1911 and warm cupboard, 19th April, 1911 (Table XXXVIII).

Temperature	Average humidity	Number of cocoons	Average duration of cocoon stage
75·2	·50	4	14 days
63·6	·60	5	44 ,,

A still greater contrast is shown in the experiment of 11th August, 1910 (Table XXXVII) in which the average duration of the cocoon stage is compared in the case of individuals reared throughout in incubator 75 Wet and the laboratory cupboard respectively.

Temperatures	Average humidity	Number of cocoons	Average duration of cocoon stage
75° F	·60	4	12 days
53 (mean)	·83	6	116 ,,

As regards humidity it is possible that the increase of ·10 in the second instance given above may be a factor in extending the cocoon period; it is probable, however, that it is unimportant and masked by the normal variation of the individual cocoons. A comparison of the different experiments in Table XXXVIII shows somewhat contradictory evidence in regard to the effects of humidity. For example, in the case of experiments in incubators 85 Dry and 85 Wet, the shorter duration of the cocoon period corresponds to the higher humidity, while a like comparison of the results in 75 Wet and 75 Dry shows that at this temperature the shorter duration usually occurs under the drier conditions. Further, if we compare the records of 75 Wet among themselves we find longer periods corresponding to lower humidity. The conclusion to be drawn is that, in comparison with humidity, temperature and individual variation are the important factors.

There is some evidence suggesting that change to cooler conditions about the spinning period is important in lengthening the cocoon stage, apart from the temperature during this stage[1]. At least this is a plausible explanation of the divergent results obtained with broods reared in the laboratory cupboard from the egg stage onwards and those transferred from a warm incubator. Two batches of newly hatched larvae were put into the laboratory cupboard on the 3rd and 12th June

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[1] Work by Merrifield on the Seasonal Dimorphism of some species of Lepidoptera shows that an otherwise latent tendency to lengthen the pupal period may be made in response to a change of temperature chiefly if not only at some one time in the larval life. *Experimental Entomology. Factors in Seasonal Dimorphism*, F. Merrifield, F.E.S. Extrait I^{er} Congrès International d'Entomologie, Bruxelles, 1910.

1911. They had reached the cocoon stage by the 12th July and 12th August respectively, and both batches had an average cocoon period of 17 days, see Table XXXVI. On the other hand in a batch of 41 cocoons transferred from incubator 75 Wet to the Laboratory cupboard on the 30th May 1911 (Table XXXVIII (*c*)) the average cocoon period of the 32 specimens that emerged, was 53 days. In the latter case the cocoon period began earlier than with the batches put in on the 3rd and 12th June, it continued over the same period, and, in the case of some individuals, was prolonged later. It seems probable that the explanation of this result is that *P. irritans* has a seasonal habit[1], passing the cold months in the cocoon period if possible. A fall of temperature of any moment, as at the approach of autumn, occurring during the late larval or early cocoon stage, brings into action some inherited tendency to lengthen the cocoon period. The length of this stage is due to individual variation as well as to the actual conditions experienced. In this connection it should also be noticed that *change* from a lower to a higher temperature near the date of spinning was also followed by a marked lengthening of the cocoon period.

Below are summarised two interesting experiments from Table XXXIX. In Exp. (*a*), under date 27th April, 1911, the cocoons were spun in the cellar and shortly afterwards transferred to incubator 85 Dry; in Exp. (*b*) (May 2nd, 1911) the cocoons suffered a less drastic change: spun in the laboratory cupboard, they were afterwards moved to incubator 75 Dry. In this case the average duration of the cocoon period was only 17 days, whereas in Exp. (*a*) it was 58 days.

	Temperature at spinning	Humidity at spinning	Transferred to temperature	Humidity	Average duration of cocoon period
(*a*)	54·1	·92	84·1	·6	58 days
(*b*)	58·0	·78	75·3	·53	17 ,,

The following experiments also give good illustration of the influence of a sudden fall in temperature in lengthening the cocoon period. In the "complex transference" experiment under date 2nd May, 1911, Table XXXIX, cocoons were spun in incubator 85 Dry, at a temperature of 84·3 F. and average humidity ·59; they were then transferred to the cellar with a mean temperature of about 57 F. during the course of the experiment. The average cocoon period was 48 days. In one of the continuous experiments, the material was kept in the cellar throughout from the egg stage (Table XXXVI under date 3rd June, 1911) at a mean temperature of about 62° F., humidity ·90. In this case the individuals passed on an average only 19 days in the cocoon. The inference appears to be that the susceptibility to sudden fall in temperature is, or may be, continued into the early period of cocoon life.

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[1] There is perhaps some indication of a seasonal habit in the fact that the November cocoons reared late in the autumn tend to show a higher mortality than in the spring and summer (see Table XXXVIII, experiments in incubator 75 Wet).

C. fasciatus. With *C. fasciatus* we find a much more complex state of affairs. Individual variation occurs as in the case of *P. irritans.* There is also conclusive evidence of lengthy resting within the cocoon under conditions of high as well as low temperature and over a wide range of humidity. This may be a simple temperature effect or due to change in temperature or both.

A close but general survey of the records obtained convinced me that there was evidence both of an aestivating and an hibernating habit in this species. Extremes both of heat as well as cold produce an effect which is partly of a direct nature and partly, perhaps, a stimulus which calls into action an inborn predisposition to prolonged rest within the cocoon under unfavourable conditions. As was found in the case of *P. irritans*, it is the *changes* in temperature which appear to be the controlling factor.

This suggestion, in spite of some contradictory evidence, is supported by a comparison of the following results, which moreover indicate that the more acute the change the greater the response. For example, in the "simple transference" experiments, detailed in Table XXXI, taking place in incubators 85 Wet and 85 Dry (Exp. (*a*) 30th Jan. 1911 and Exp. (*b*) 24th March, 1911) there is a break in the record of emergences between about the 25th day and the 70th day after the cocoons were transferred. The results of the same experiments are graphically expressed in Charts 7 and 8, in which the double period of emergence is clearly shown.

If I am not mistaken, this same feature may be observed in the other experiments (see, for example, Tables XXXI and XXXII and Chart 9) though not so clearly, and the suggestion is that we have here traces of an inherent discontinuity in the development of this species which in nature may favour a spring or autumn emergence of adults. It is an interesting question whether the individuals whose emergence is delayed by heat are the same as those whose emergence may be delayed by cold, or if the influence of extremes of temperature varies in different individuals. While there is no direct evidence

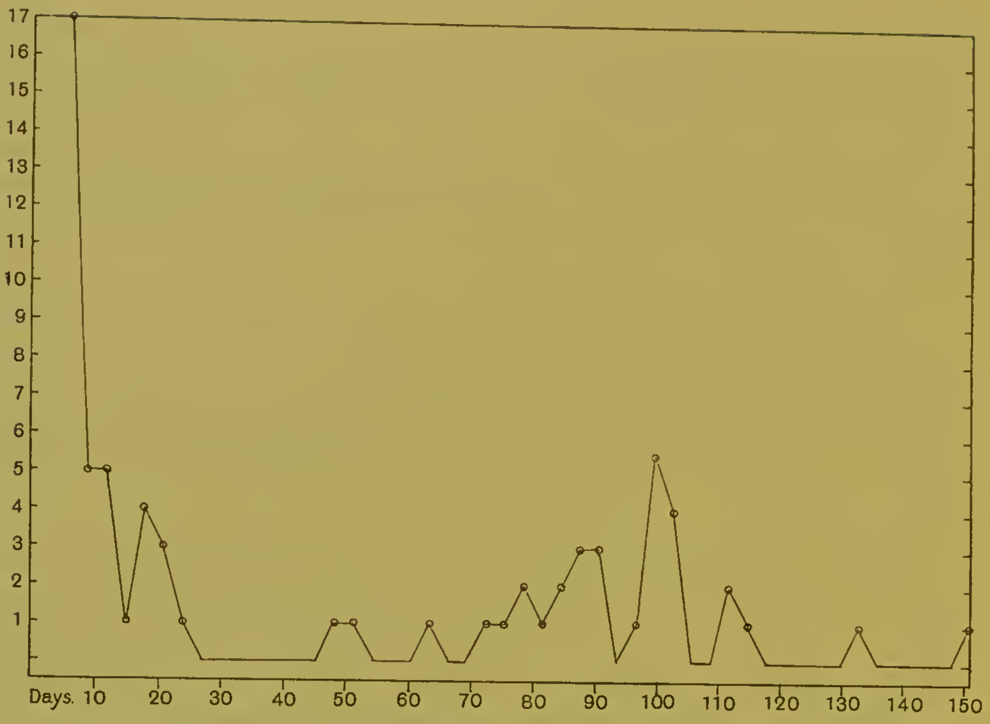

Chart 7. Emergence of *C. fasciatus* from cocoons in Incubators 85 Dry and 85 Wet (see Exps. Jan. and March 1911, Table XXXI, Nov. 1910 and April 1911, Table XXXII).

Temperature approximately 84° F.
Humidity average between ·60 to ·76.
Vertical numbers = units of emergence. Horizontal numbers = time in days (3 day units).

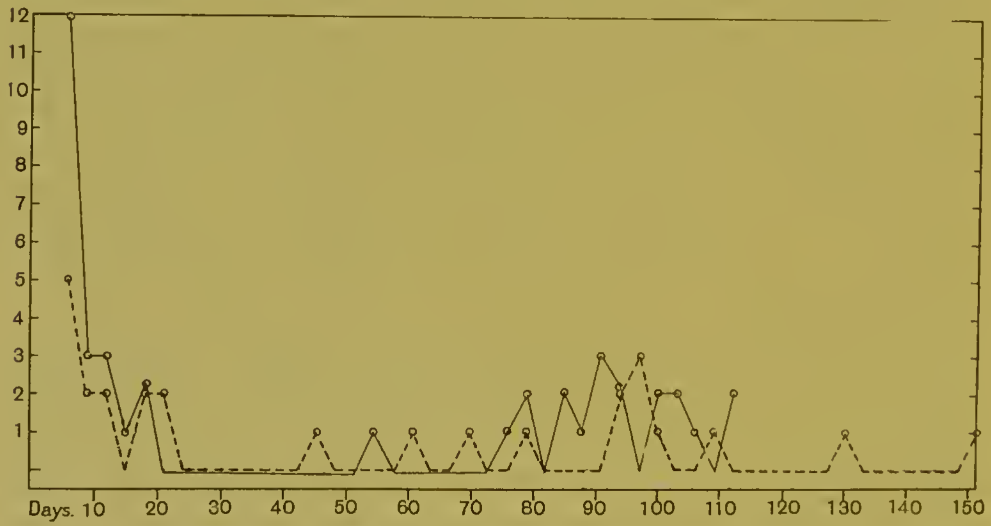

Chart 8. Emergence of *C. fasciatus* from cocoons in Incubators 85 Dry and 85 Wet (see Tables as Chart 7).

Continuous line, 85 Wet. Temperature 84° F. Humidity average ·70 to ·76.
Dotted line, 85 Dry. Temperature 84° F. Humidity average ·60 to ·63.
Vertical numbers = units of emergence. Horizontal numbers = time in days (3 day units).

on this point for this series, we may note the fact that the individuals reared under cool conditions in the cellar (7th October, 1910, Table XXVIII) during the autumn of 1910, assumed the cocoon stage during mid-winter, did not emerge during the spring but during the late summer and autumn of the following year. That is to say, that a proportion of them, after being reared under cool humid conditions, resisted the summer range of temperature with a mean average of above 60° F. for three months, and commenced their adult life on a falling temperature during the autumn of 1911.

A similar occurrence is also apparent in the Tables dealing with the cocoons spun in incubator 75 Wet, and then distributed to the cellar, laboratory cupboard and beehive (Table XXXI and Charts 10 to 12), and in the "complex transference" series, under date 8th November, 1910 (Table XXXII) spun in incubator 85 Wet, and then transferred to the cellar. No emergences at all took place between the 68th and 236th day after the cocoons were placed in the cellar. Perhaps the most striking example is afforded by an experiment in which cocoons were transferred from incubator 75 Wet to the beehive on the 23rd March, 1911 (see Table XXXI (*b*)). When the cocoons were put in, the mean temperature was only 42·9° F., yet some of the individuals resisted the high summer temperature of 1911, which reached a maximum average of 80° F. for the months of July and August, and emerged at much lower temperatures during the autumn.

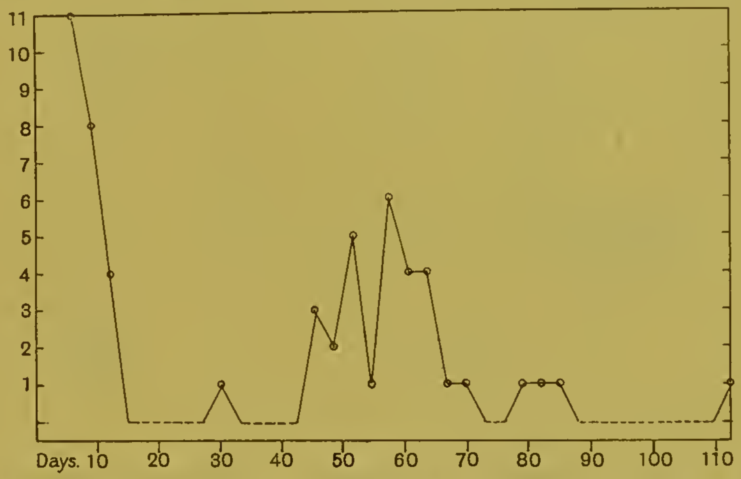

Chart 9. Emergence of *C. fasciatus* from cocoons in Incubator 75 Wet (see Exps. Jan., Feb., March 1911, Table XXXI, Nov. 1910, Table XXXII).

Temperature 74·6 to 75·5 F.
Humidity average from ·76 to ·84.
Vertical numbers = units of emergence. Horizontal numbers = time in days (3 day units).

Drought would appear to lengthen the average resting period in the cocoon at 85° F. and 92° F., and to shorten it at the lower temperature of 75° F. While there are some contradictions to be found in the tables, they do not counterbalance the general conclusion, and the massed evidence of the monthly series of tests—to be referred to immediately—is of the same tenor. The differences are not large, the duration of the cocoon period being on an average 25·3 days in 75 Wet, as against 23·8 days in 75 Dry, while at the higher

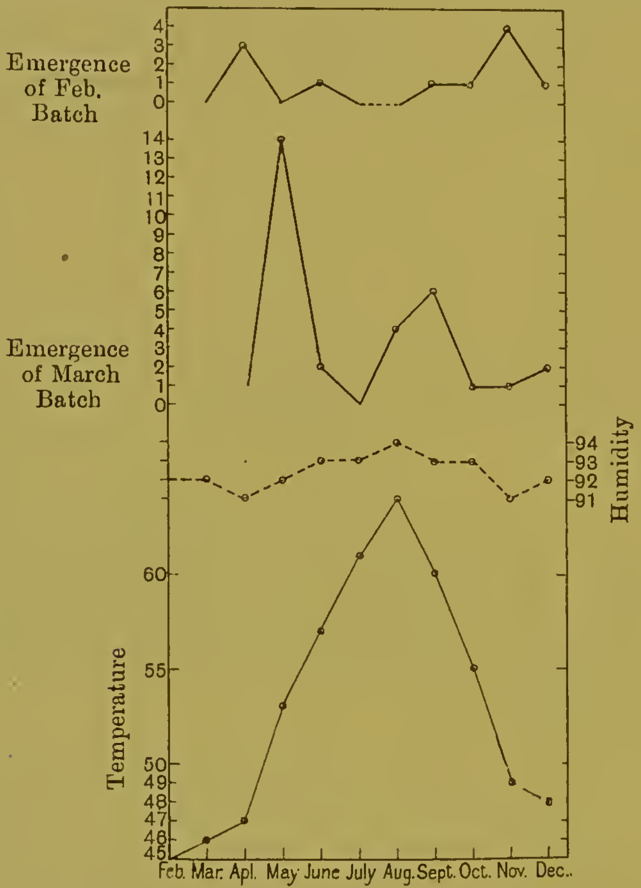

Chart 10. Influence of Temperature and Humidity upon the emergence of *C. fasciatus* from cocoons. CELLAR (see Exps. Feb. and March 1911, Table XXXI).

Two batches: one put in Feb., one put in March 1911.
Vertical numbers at top of chart give units of emergence (two series).
,, ,, on Left, mean Temp. F°.
,, ,, on Right, Humidity.
Horizontal divisions, time (monthly units).

Explanation. The two curves at the top of the diagram express the numbers of fleas emerging at monthly intervals of time. The dotted line represents the variation in humidity and the lower continuous line the variation of temperature during the period of experiment.

temperatures it is only 21·6 days in 85/93 Wet and 32·7 days in 85/93 Dry.

A very extensive series of experiments, of which only the summaries are included in Table XXXIII, were undertaken in order to investigate the existence of a seasonal fluctuation in the constitution of *C. fasciatus* which might influence the length of the resting period apart from the temperature. Full grown larvae were taken from the cages in large

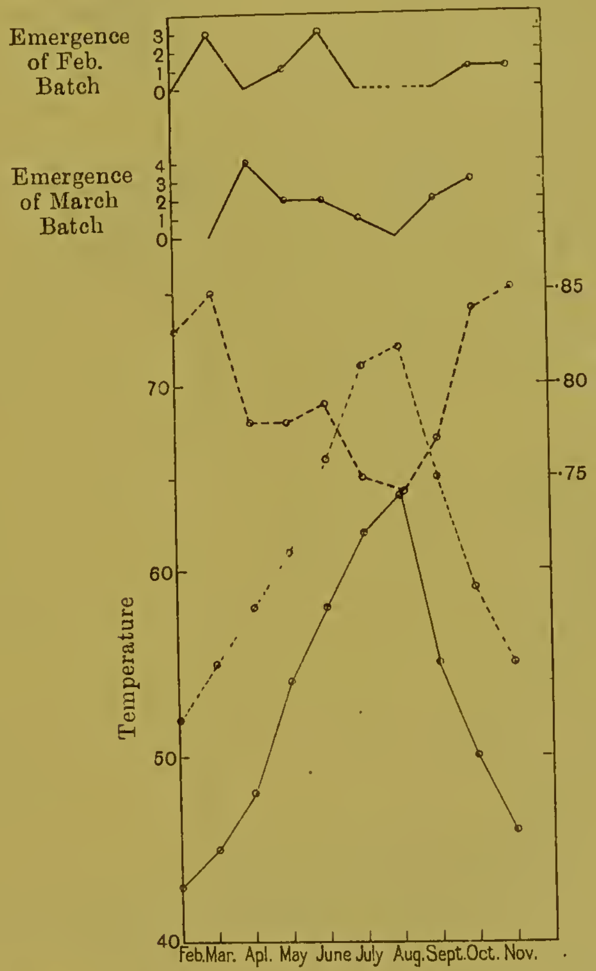

Chart 11. Influence of Temperature and Humidity upon the emergence of *C. fasciatus* from cocoons. Laboratory Cupboard (see Exps. Feb. and March 1911, Table XXXI).

Two batches put in Feb. and March 1911.
Vertical numbers at top of chart give units of emergence (two series).
,, ,, on Left, Temp. F°.
,, ,, on Right, Humidity.
Horizontal divisions, time (monthly units).

Explanation as for Chart 10, except that temperature is represented by two curves (maxima and minima).

batches each month and placed in incubator 75 Wet, so that all the cocoons might be spun under conditions as nearly similar as possible. The cocoons were then divided into batches and distributed among the different incubators, cupboards, etc. as far as possible on identical dates.

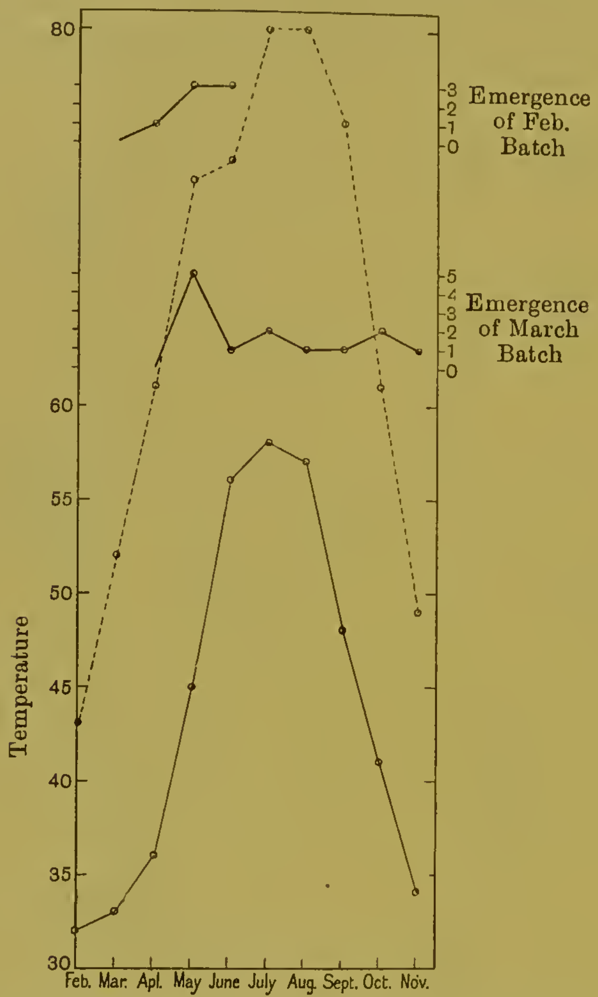

Chart 12. Influence of Temperature on emergence of *C. fasciatus* from cocoons (see Exps. Feb. and March 1911, Table XXXI).

Record of two batches in Beehive.

Vertical numbers on Right, units of emergence (two series). On Left, Temp. F.° scale.

Horizontal divisions, time (monthly unit).

Explanation as for Chart 11.

Both in mortality and in tendency to "rest," there is no very clear indication of a seasonal change. The November cocoons certainly showed very definite intolerance of heat and drought. In the cool situations on the other hand there was a very marked tendency for them to have prolonged resting periods, the average length of the cocoon period for this month being easily ahead of the others. The cocoons were also for the most part very hard.

Although the question cannot be regarded as settled, the results of the November series appear to negative the suggestion made on p. 539 that individuals which achieve lengthy periods of rest in response to cold were equally fitted for rest under hot conditions.

In short, the cocoon period of *C. fasciatus* is constitutionally a very varied one. It is possibly more correct to regard the species as having a certain percentage of individuals adapted for long resting periods in the face of extreme conditions of temperature, but susceptible to comparatively quick development in response to "warm" conditions (70° F.). There is also evidence which suggests that a "spring-autumn" emergence is favoured; individuals which have started to rest in response to low temperature resisting the early summer rise, continuing their rest in spite of a rising temperature and emerging during the autumn. It is even within the bounds of possibility that a second winter might be passed as larvae resting within the cocoons, since I have several instances of larvae resting for periods of over a year.

That a larger proportion of individuals achieve a lengthy rest under cool than hot conditions is perhaps a racial question; were we to experiment with a race of *C. fasciatus* which came from a warmer country than England, it is possible that the position might be reversed.

An experiment dealing with retarded emergence (Table XLIII) was made in the early spring of 1911. A large number of adult *C. fasciatus* were required to stock a new cage, and some 400 to 500 full-grown larvae were, therefore, taken from the cages, put into card jars with sand and shreds of B.S. rag and placed in incubators 75 Wet and 85 Wet. The fleas that emerged during March and April were used for the above purpose and did not form the subject of any special notice but the jars were examined every two or three days during May and onwards for "laggards."

The results are set forth in Table XLIII; this does not specifically belong to either the cocoon or larval series, it being uncertain when the cocoon period actually commenced. It is, however, probable that the greater portion of the time between the removal of the larvae from the cages and their emergence as fleas was passed within their cocoons. The Table is therefore included in this section and, as the numbers dealt with are considerable, they afford valuable testimony in support of the experiments, showing what a long period (up to 150 days) may elapse, even under the influence of warm to hot conditions, before the full development of the adult is attained.

As regards the first batch, about 120 larvae were added to a jar contained in incubator 75 Wet on the 27th January, 1911; on the 4th March a further batch of larvae were added to this jar. The number of days stated are counted from the 4th March, although it is not improbable that some of the later records really belong to the January batch of larvae.

The cage referred to on p. 545 was stocked with some 200 to 250 fleas which may be termed the "forwards" of these batches. I am informed by Dr Boycott, in whose charge the cage remained for some two or three months, that three successive broods were observed in the cage with distinct intervals between them, during which the flea population fell to a minimum; very few individuals were seen in the intervals, but during the waves of emergence the cage swarmed with fleas.

X. cheopis (Tables XXXIV and XXXV). The effects of temperature are clear and unmistakable, the lengthening of the cocoon period being very marked at temperatures below 65° F.; situations with a mean temperature below this level as a rule give rise to a long rest within the cocoon. 65° F. would seem for this species to be equivalent to about 50° F. for *P. irritans* and 40 to 45° F. for *C. fasciatus*.

In the June 1911 series of experiments set forth in Table XXXV, the average duration of the cocoon stage in the incubators (15·5 days) is shorter than it was in the September experiments (21 days). As the other conditions in the two series were approximately the same, this difference suggests that some predisposing cause acted on the larvae before they were taken from the cages for the September experiment. Such an influence is probably not far to seek. Towards the end of September the temperature in the cages would be lower than during June, and it is also possible that the fall of temperature experienced by the larvae between the months of August and September may have provided the necessary stimulus for a longer resting period in the cocoon stage.

The degree of humidity does not seem to have had any marked influence on the length of rest in the cocoon. In the June series, there appears to be a slight advantage in the greater humidity of incubators, 85 Wet and 75 Wet, resulting in a shorter average length of cocoon period; this is, however, reversed in the September experiments when the incubators, 85 Dry and 75 Dry, give the shorter average. Corresponding contradictions are obtained when similar comparisons are made between other experiments in Table XXXV.

The results obtained are antagonistic to any supposition of an aestivating habit in the stock of *X. cheopis* used for these experiments.

In the September experiments of Table XXXV made in incubator 75 Wet, periods of 71 and 94 days in the cocoon were recorded. In the laboratory cupboard and cellar during the summer still longer times were taken for development. This must, I think, be regarded as a rest in response to moderate and cool conditions. This species is naturally adapted to a hot rather than a warm climate: a fact that is fully borne out by the susceptibility to cold or even cool conditions shown throughout these experiments.

At the high temperature of 93° F. the mortality of this species is not by any means prohibitive, provided the humidity is sufficient. Comparison of the results in the Wet and Dry incubators given under May, 1912, show this quite well (see Table XXXV).

The facts are, however, rather puzzling, with 93 Dry. They are more so in regard to 75 Dry, as the lowest readings of humidity were not by any means always accompanied by the highest mortality, and it is clear that there must be some disturbing factor. This may be due to the varied amount of ventilation that it is necessary to give to the incubators in order to keep the humidity as steady as possible. In December, where low figures for mortality were recorded, the ventilators were kept shut and all draught avoided. I fancy that the results are also affected by variation in the larvae, both in the matter of general vitality, which causes them to spin stronger or slighter cocoons (the flimsy ones being ill fitted to resist desiccation) and also in regard to the stage of preparation they have reached for the approaching metamorphosis before the cocoons are transferred to the dry incubators.

These results can only be taken to apply exactly for the race of English *X. cheopis* that were experimented with. It is quite possible that other races may possess greater powers of resistance to both heat and drought.

Ct. canis. The four Tables (XL (*a*), (*b*), (*c*) and (*d*)) dealing with this flea are not strictly comparable with each other. In the case of the earliest series under date 17th November 1910 (Table (*b*)) the figures recorded are definite as to dates of emergence but not as to the time of spinning; consequently the number of days calculated as the cocoon period are only approximate. With the July series (Table (*c*)), however, both series of dates are correct, but the number of cocoons used is approximate only; it was not possible to count them owing to their being spun together in masses. The experiment was the outcome of a chance opportunity and we were too busily employed with definitely planned work to spare the time necessary to separate and count some 1300 cocoons used for this and the submergence trials. The figures given in the two April experiments (Table (*a*)) are also only approximate and may almost as correctly be supposed to deal with the larval as with the cocoon stage. The cocoons were left to emerge where the larvae span, with the consequence that there were emergences from cocoons that were not found. The experiment serves, however, to illustrate the effect of different conditions corresponding to incubator 75 Wet and the cellar in modifying the time of emergence, as both batches of larvae were placed under the test conditions on the same date.

It is to be noted that all the *Ct. canis* experiments are from stock naturally reared, not obtained from eggs laid under controlled conditions, nor, as with the rat fleas, bred from adults kept under exceptional, if favourable conditions. Of the November series (Table XL (*b*)) it may be remarked that the cellar experiment gives an approximately natural result; probably under out-of-door conditions in a kennel the emergence would have been some three weeks later. It is likely that the April series of larvae (Table XL (*a*)) are the progeny of adults that emerged in the spring about March, and the July larvae (Table XL (*c*) and (*d*)) follow from the adults reared from the April larvae. Such a basis suggests that *Ct. canis* produces about four or five broods a year according to the season, but it is probable that there would be overlapping of the fleas from each brood and a general emergence in August, provided warm weather prevailed. Some of the fleas emerging in autumn would probably survive the winter, but there would be few, if any, late autumn emergences under out-of-door conditions. The approximate unanimity displayed by this species in the incubators as regards the date of emergence of different individuals in one batch of cocoons (Table XL (*c*)) marks it off distinctly from the rat and human fleas and it seems not unlikely that the plagues of fleas said to occur suddenly, especially during late summer, are of this species.

Like *X. cheopis*, I can see no evidence of an aestivating habit from the recorded results in Table XL. A slender tail of laggards to each of the several batches makes considerably more show when the conditions are cool and moderate. Quite possibly many of these laggards are destroyed if high temperatures prevail.

Unfortunately no mortality figures can be given, as the cocoons were spun in masses, and at the period when this material was available there was no time to separate and count the cocoons accurately.

C. gallinae (Table XLI). The numbers available were too small to allow any but initiatory trials to be made and nothing very definite can be based on the results obtained. The chief items of interest would seem to be the low mortality in incubator 75 Dry, the frequent emergence of larvae from their cocoons followed by successful pupation and the fact that the mortality is so largely in the pupal stage. There is no evidence suggesting that this species may have an extended larval resting period within the cocoon.

L. musculi (Table XLII). A preliminary experiment, like that with *C. gallinae*, was undertaken; it is of some interest, but hardly affords basis for any final conclusions. This flea seems to be well adapted for the cool to moderate summer conditions of the cupboards, cellar and beehive, but not able to adjust itself readily to the high temperature of 93° F., although there is some evidence of its following *C. fasciatus* in attempting to meet unfavourable conditions both of heat and cold by resting. The recorded periods of rest are not comparable with those of *C. fasciatus*—this must be put down to want of opportunity, as it is quite uncertain how long the few examples that are now resting may take before emergence.

L. musculi would seem to be quite well adapted for conditions of low humidity in the cocoon stage—a fact that is significant, if we consider the habits and surroundings of its hosts in comparison with other flea hosts.

TABLE XXVIII. *Cocoons* C. fasciatus. "*Continuous*" *series, reared from eggs, each batch maintained during egg, larval, and cocoon stage in the same situation.*

Incubator 75 Wet

Date of commencement of experiment in the egg (or larval) stage, see note below *	No. of cocoons found	Temperature	Humidity	Approximate duration of cocoon stage † (No. of cocoons)	Days	Average number of days in cocoon	Mortality in cocoon stage	Food during larval period	Remarks
24 Sept. '10	7	74·4	·74	3	7	11	Nil	B.S. Rag	—
				4	14				
16 Oct. '10	1	74·1	·73	1	12	12	Nil	Rat faeces	—
30 ,,	8	74·2	·73	4	9	10	Nil	,,	—
				2	10				
				1	11				
				1	14				
,, ,,	13	74·2	·73	3	8	10	Nil	B.S. Rag	—
				1	9				
				6	10				
				2	11				
				1	14				
21 Dec. '10	8	74·6	·72	1	6	16	12 %	,,	—
				4	11				
				1	13				
				1	18				
14 Mar. '11	10	75·0	·79	1	6	11	?	Rat faeces chopped fine	5 cocoons opened 11 Aug. '11 found to be empty, probably false cocoons
				1	10				
				2	12				
				1	17				
24 April '11	3	75·5	·88	3	15	15	Nil	Powdered blood	—

23 May '11	20	76·0	·86	5	9	13	Nil	Flea faeces	—
				8	12				
				6	14				
				1	44				
,, ,,	7	76·0	·86	—	—	—	?	Rat faeces	Cocoons opened 23 Aug. '11 all empty
,, ,,	21	75·7	·85	6	9	12	5 %	B.S. Rag	1 cocoon opened contained dried up larva
				7	12				
				7	14				
						Incubator 85 Wet			
22 Sept. '10	5	84·3	·72	No records, all emerged		No records	Nil	B.S. Rag	—
15 Mar. '11	6	84·3	·71	1	4	7	Nil	Rat faeces chopped fine	—
				3	7				
				1	9				
				1	12				
8 July '11	29	Aug. 84·7	·81	3	24	44	20 %	B.S. Rag	Remaining cocoons opened 1 Dec. '11 contained 1 dried up flea, 5 dried up larvae, 1 empty cocoon
		Sept. 84·8	·78	6	25				
		Oct. 84·8	·78	3	32				
				2	43				
				2	47				
				1	69				
				1	71				
				3	75				
				1	103				
8 ,,	No cocoons	—	—	—	—	—	—	Rat faeces	—
13 ,,	6	84·9	·80	1	36	40	Nil	Flea faeces	Remaining cocoon opened and found empty, false cocoon
				1	40				
				2	40				
				1	43				

* NOTE. Experiments in Table XXVIII (up to 14 Feb. 1911) are in direct continuity with those dealing with the egg stage given in Table II and (up to 25 June 1911) with larval stage experiments given in Table XVI.

† NOTE. It was not possible to fix the exact date of spinning; the days in cocoon (reckoned from the finding of the cocoons) are likely to be too few but their relation to each other should be correct.

TABLE XXVIII.—*Continued.*

Laboratory Cupboard

Date of commencement of experiment in the egg (or larval) stage	Number of cocoons found	Temperature	Humidity	Approximate duration of cocoon stage (No. of cocoons)	Days	Average number of days in cocoon	Mortality in cocoon stage	Food during larval period	Remarks
6 Aug. '10	1	60 (approximate only to 8 Nov.) max. min. Nov. 54·0 42·8 Dec. 56·5 47·8	·84 ·84 ·85	1	102	—	—	B.S. Rag	Cocoon opened 1 Jan. '11 and found to contain a living larva
12 ,,	4	60 (approximate only to 8 Nov.)	·84	1 1 1	23 25 28	26	Nil	,,	—
				Cellar					
		max. min							
31 July '10	1	58·0 57·0	about ·93	1	27	—	Nil	,,	—
4 Aug. '10	3	58·0 57·0	about ·93	1 2	21 29	26	Nil	,,	—
14 ,,	1	58·0 57·0	about ·93	1	30	—	Nil	,,	—
7 Oct. '10	12	Dec. 50·0 48·8	·93	2	203	236	—	,,	1 opened 8 May '11 and found to contain a resting larva. Larva placed in small tube in 75 Wet, it died without undergoing change to pupa
	2 30/12/10	1911		1	219	(cocoon			
	1 2/ 1/11	Jan. 46·5 45·3	·92	2	224	opened			
	6 9/ 1/11	Feb. 46·4 44·8	·92	2	269	21 Oct. '11			
	1 19/ 1/11	Mar. 46·5 45·3	·91	1	285	contained			
	2 28/ 1/11	April 48·5 46·6	·91			living flea)			
		May 53·9 52·6	·92						
		June 58·1 56·7	·93						
		July 61·6 60·4	·93						
		Aug. 64·5 63·4	·94						
		Sept. 60·6 59·5	·93						
		Oct. 56·3 54·8	·92						

		max. min.							
4 April '11	3	Nov. 50·7 48·9	·91	—	—	—	—	Rat faeces	2 fleas emerged, 1 on 12 June, 1 on 27 July, but the cocoons they came from were not found
		Dec. 48·7 47·4	·92						
		1912							
		Jan. 47·2 45·9	·92						
		Feb. 45·8 44·6	·92						
18 June '11	32 21 July	see above	—	2	19	71	—	Flea faeces	1 cocoon opened contained dried up pupa
				3	26				
				3	31				
				4	39				
				3	41				
				2	47				
				2	54				
				1	61				
				1	70				
				1	81				
				1	97				
				1	105				
				2	121				
				1	131				
				1	138				
				1	194				
				2	207				
25 ,,	27 21 July	see above	—	1	13	27	—	B.S. Rag	1 cocoon false, neither dried remains nor cast skin
				4	19				
				9	26				
				4	25				
				6	31				
				1	41				
				1	54				

TABLE XXIX. *Cocoons* C. fasciatus. "*Continuous*" *series reared from eggs.*

Incubator 75 Wet (moistened during the larval period)*

Date of commencement of experiment in the egg (or larval) stage, see note below†	Number of cocoons found	Temperature	Moistened	Approximate duration of cocoon stage‡ (No. of cocoons)	Days	Average number of days in cocoon	Mortality in cocoon stage	Food during larval period	Remarks
13 Jan. '11	9	73·7	Water	2 3 1 1 1	13 14 26 27 36	19	11 °/₀	B.S. Rag	1 cocoon opened and found to contain a dead flea
28 Dec. '10	6	74·7	Urine	2 1	11 10	11	50 °/₀	,,	3 cocoons opened and dead fleas found in them
,,	14	74·6	Water	2 2 1	13 18 21	16	64 °/₀	,,	9 cocoons opened contained 8 dead larvae, 1 dead flea
4 Mar. '11	2	74·6	Urine	2	13	13	Nil	,,	only 2 cocoons found
,,	1	74·6	Water	1	10	10	Nil	,,	—
				Incubator 75 Dry					
31 Jan. '11	3	75·7	Water daily	1	10–13	—	67 °/₀	,,	2 cocoons opened contained dead larvae
,,	No cocoons	—	Urine daily	—	—	—	—	,,	—
				Incubator 85 Wet					
30 Dec. '10	7	85·3	Urine at intervals	5	13	—	29 °/₀	,,	2 cocoons opened contained dried up pupae
,,	No cocoons	—	Water at intervals	—	—	—	—	,,	—
24 Feb. '11	2	83·5	Urine 1 c.c. daily	1 1	3 6	5	Nil	,,	—
,,	4	84·2	Water 1 c.c. daily	1 1	16 20	18	50 °/₀	,,	2 cocoons opened contained dead larvae

Incubator 85 Dry

21 Feb. '11	2	84·0	Water 1 c.c. daily	1 1	13 14	—	Nil	B.S. Rag	—
,,	No cocoons	—	Urine 1 c.c. daily	—	—	—	—	,,	—
15 May '11	6	June 83·9 July 84·2	Water ·5 c.c. daily	1 1 1	13 34 55	34	50 %	,,	3 cocoons opened contained dried up larvae
6 ,,	13	May 84·0 June 83·9 July 83·5	Urine ·5 c.c. daily	4 1 5 1 1	7 15 21 39 41	19	8 %	,,	1 ,, ,, ,,

Warm Cupboard

NOTE. No larvae of unmoistened experiments lived to spin cocoons in this cupboard.

3 Feb. '11	1	63·5	Water daily	1	18	—	Nil	,,	—
,,	No cocoons	—	Urine daily	—	—	—	—	,,	—
8 Mar. '11	10	68·1	Water 1 c.c. daily	2 2 1 1 3 1	12 16 18 22 24 23	19	Nil	,,	—
,,	No cocoons	—	Urine 1 c.c. daily	—	—	—	—	,,	—
5 May '11	7	66·8	Urine ·5 c.c. daily	1 1 1	16 17 31	21	57 %	,,	4 cocoons opened contained dried up larvae
6 ,,	6	65·3	Water ·5 c.c. daily	1 1 1 1	9 14 15 20	14	33 %	,,	2 ,, ,, ,,

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* No larvae in case of experiments under unmoistened conditions in incubators 75 Dry and 85 Dry survived to spin cocoons.

† Experiments in Table XXIX are in direct continuity with those dealing with the larval stage given in Table XVII, and (up to 8 March 1911) egg stage in Table I.

‡ The numbers given for the duration of the cocoon stage are likely to be too small but should bear a correct relation to one another; the date of spinning is uncertain, the date of finding the cocoon was alone recorded.

TABLE XXX. *Cocoons* C. fasciatus. *"Continuous" series, contrasted experiments (compiled from Table XXVIII); larvae from same batch of eggs.*

(*a*) Reared on the same food under different conditions of Temperature and Humidity.

Date of commencement of experiment in the larval stage	Place Reared from egg in	Food	Number of cocoons found	Temp	Humidity	Approximate duration of cocoon stage (No. of cocoons)	Days	Average number of days in cocoon	Mortality in cocoon stage
14 March '11	Incubator 75 Wet	Rat faeces crushed	10	75·0	·79	1	6	11	Doubtful if any
						1	10		
						2	12		
						1	17		
						5 cocoons opened 11 August '11 and found empty, probably false cocoons			
15 March '11	Incubator 85 Wet	,,	6	84·3	·71	1	4	7	Nil
						3	7		
						1	9		
						1	12		

(*b*) Reared under the same conditions of Temperature and Humidity but on different food.

Date of commencement of experiment in the egg stage		Reared from hatching on							
30 Oct. '10	Incubator 75 Wet	B.S. Rag	13	74·2	·73	3	8	10	,,
						1	9		
						6	10		
						2	11		
						1	14		
,,	,,	Rat faeces	8	74·2	·73	4	9	10	,,
						2	10		
						1	11		
						1	14		

Table XXXI (*a*). *Cocoons* C. fasciatus. *Full grown larvae taken from the breeding cages and allowed to spin in Incubator* 75 *Wet* (*Temperature* 74° *F., Humidity* ·70); *cocoons then placed in different situations.*

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature	Humidity	Dates of emergence of fleas		No. of days in cocoon	Average days	Remarks
30 Jan. '11	15	Incubator 85 Wet	84·0	·70	4	7 Feb. '11	8	32	23 March '11. Examined, 5 "soft" all empty, 3 "hard" contained resting larvae 7 June '11. 5 "hard" and 1 "soft" opened, 1 contained living resting larva, remainder contained either dried up larvae or cast larval skins. Mortality doubtful
					1	10 ,,	11		
					2	13 ,,	14		
					1	20 ,,	21		
					1	16 April '11	76		
					1	21 ,,	81		
					1	12 May '11	102		
,,	15	Incubator 85 Dry	84·1	·60	2	7 Feb. '11	8	41	19 Feb. '11. 7 empty cocoons opened all "soft" or tending in that direction, but not flimsy cocoons, the silk forming a continuous papery lining. One very little if at all stronger contained a resting larva. 7 "hard" cocoons unopened. Mortality doubtful 7 June '11. One of the hard cocoons opened found to contain a living pupa, the adult flea within the pupal envelope being nearly ready to emerge. Mortality doubtful
					2	8 ,,	9		
					1	20 ,,	21		
					1	23 ,,	24		
					1	24 ,,	25		
					1	6 April '11	66		
					1	27 ,,	87		
					1	3 July '11	154		
,,	15	Incubator 75 Wet	75·5	·76	3	7 Feb. '11	8	35	23 March '11. 6 "soft" cocoons opened, 4 empty, 1 contained pupa with flea nearly ready to emerge, 1 a dead flea. 2 "hard" cocoons contained "white," that is recently developed, pupae 7 June '11. Remainder of cocoons opened contained either dried up larvae or cast larval skins. Mortality doubtful
					1	10 ,,	11		
					1	21 March '11	50		
					2	24 ,,	53		
					1	2 April '11	62		
					1	3 ,,	63		
,,	15	Incubator 75 Dry	75·6	·49	3	7 Feb. '11	8	26	13 March '11. 1 hard cocoon opened contained a resting larva which successfully pupated and an adult flea was reared on the 25th March, see column 6* Note the silk of this cocoon was hard and brown forming an almost horny lining to the cocoon June '11. Remaining cocoons opened contained dead larvae. Mortality 20 %
					1	8 ,,	9		
					2	13 ,,	14		
					1	14 ,,	15		
					1	17 ,,	18		
					1	18 March '11	47		
					*1	25 ,,	54		
					1	27 ,,	56		
					1	31 ,,	60		

TABLE XXXI (*a*)—*Continued.*

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature			Humidity	Dates of emergence of fleas		No. of days in cocoon	Average days	Remarks
				max.	min.						
1 Feb. '11	13	Lab. cupboard	Feb.	52·8	43·6	·83	1	16 ,,	43	118	23 March '11. 3 "soft" cocoons opened all empty, 2 slightly firmer contained 1 "white" pupa, 1 "resting" larva. 2 "hard" cocoons opened, 1 was empty, 1 contained resting larva. 3 Oct. '11. 2 cocoons opened, 1 was entirely empty, 1 contained a living flea*, see column 6 21 Oct. '11. 1 cocoon opened contained a living pupa. Mortality doubtful
			Mar.	52·2	45·5	·85	1	23 ,,	50		
			April	58·2	48·2	·78	1	30 ,,	57		
			May	61·8	54·3	·78	1	23 May '11	80		
			June	66·4	58·2	·79	1	1 June '11	89		
			July	71·5	62·7	·75	1	10 ,,	98		
			Aug.	72·0	64·1	·74	1	20 ,,	108		
			Sept.	65·7	55·7	·77	*1	3 Oct. '11	244		
			Oct.	59·0	50·9	·84	1	21 Nov. '11	293		
			Nov.	54·9	46·1	·85					
,,	13	Cellar	Feb.	46·4	44·8	·92	1	8 April '11	66	209	Remaining cocoons opened and found empty, i.e. "false" cocoons. Mortality nil
			Mar.	46·5	45·3	·91	1	13 ,,	71		
			April	48·5	46·6	·91	1	15 ,,	73		
			May	53·9	52·6	·92	1	20 June '11	139		
			June	58·1	56·7	·93	1	26 Sept. '11	237		
			July	61·6	60·4	·93	1	16 Oct. '11	257		
			Aug.	64·5	63·4	·94	2	9 Nov. '11	281		
			Sept.	60·6	59·5	·93	2	20 ,,	292		
			Oct.	56·3	54·8	·92	1	11 Dec. '11	313		
			Nov.	50·7	48·9	·91					
4 Feb. '11	9	Beehive	Feb.	43·8	30·7	Not recorded	1	22 April '11	77	103	25 Sept. '11. Two cocoons opened contained dried up larvae Mortality 22 %
			Mar.	52·5	33·3		2	2 May '11	87		
			April	61·7	36·8		1	30 ,,	115		
			May	72·8	45·2		2	6 June '11	122		
			June	73·0	56·5		1	10 ,,	126		
15 Feb. '11	13	Warm cupboard		64·3		·53	1	1 March '11	14	—	19 March '11. 5 "soft" cocoons opened contained dead larvae, 7 "hard" cocoons opened also contained dead larvae *Note.* None of the cocoons were of equal strength aud texture to the "hard" cocoons in the incubators Mortality 92 %

in Incubator 75 Wet (Temperature 74·3° F., Humidity ·76); cocoons then placed in different situations.

Special experiment with cocoons from one batch of larvae taken from cages on the same date, 24 March 1911.

Date on which the cocoons were placed under test conditions	Number of cocoons	Place	Temperature	Humidity	Dates of emergence of fleas		No. of days in cocoon	Average	Mortality	Remarks
24 March '11	15	Incubator 85 Wet	84·0	·76	5	2 April '11	9	24	27 %	Remaining cocoons opened 2 Oct. 1911 and found to contain dried up larvae
					2	3 ,,	10			
					1	4 ,,	11			
					1	6 ,,	13			
					1	13 June '11	81			
					1	4 July '11	102			
23 March '11	15	Incubator 85 Dry	84·0	·60	1	31 March '11	9	46	27 %	Remaining cocoons opened 23 Oct. 1911 contained 3 dried up fleas, 1 dried up larva
					1	2 April '11	11			
					1	3 ,,	12			
					1	7 ,,	15			
					1	8 ,,	16			
					1	15 ,,	23			
					1	19 ,,	27			
					1	9 June '11	78			
					3	5 July '11	104			
24 March '11	15	Incubator 75 Wet	75·4	·84	2	3 April '11	10	62	27 %	Remaining cocoons opened 2 Oct. 1911 contained dried up larvae
					1	14 May '11	53			
					1	22 ,,	59			
					1	23 ,,	60			
					1	24 ,,	61			
					1	30 ,,	67			
					1	14 June '11	82			
					1	15 ,,	83			
					1	19 ,,	87			
					1	17 July '11	115			
,,	15	Incubator 75 Dry (II)	75·7	·47	2	3 April '11	10	11	80 %	Remaining cocoons opened 28 Sept. 1911 contained dried up larvae
					1	6 ,,	13			
,,	15	Incubator 75 Dry (I)	75·7	·47	2	3 ,,	10	11	76 %	Remaining cocoons opened 28 Sept. 1911 contained dried up larvae
					1	4 ,,	11			
					1	6 ,,	13			
,,	15	Lab. cupboard	max. min. March 55·2 45·5	·85	4	29 ,,	36	108	7 %	1 cocoon opened contained dried up larva
			April 58·2 48·2	·78	2	9 May '11	46			
			May 61·8 54·3	·78	1	17 June '11	85			
			June 66·4 58·2	·79	1	23 ,,	91			
			July 71·5 62·7	·75	1	27 July '11	125			
			Aug. 72·0 64·1	·74	1	20 Sept. '11	180			
			Sept. 65·7 55·7	·77	1	22 ,,	182			
			Oct. 59·0 50·9	·84	1	9 Oct. '11	199			
					1	13 ,,	203			
					1	23 ,,	213			

TABLE XXXI (*b*)—*Continued.*

Date on which the cocoons were placed under test conditions	Number of cocoons	Place	Temperature	max.	min.	Humidity	Date of emergence of fleas	No. of days in cocoon	Average	Mortality	Remarks
24 March '11	15	Cellar I	March	46·0	44·7	·93	2 13 May '11	50	100	Nil	—
			April	48·5	46·6	·91	2 18 ,,	57			
			May	53·9	52·6	·92	3 27 ,,	64			
			June	58·1	56·7	·93	1 3 June '11	70			
			July	61·6	60·4	·93	1 26 ,,	93			
			Aug.	64·5	63·4	·94	2 9 Aug. '11	138			
			Sept.	60·6	59·5	·93	2 21 ,,	150			
			Oct.	56·3	54·8	·92	1 14 Sept. '11	174			
			Nov.	50·7	48·9	·91	1 26 ,,	186			
,,	15	Cellar II	(as above)				1 13 May '11	50	140	Nil	—
							4 18 ,,	57			
							2 27 ,,	64			
							1 11 Sept. '11	171			
							1 19 ,,	179			
							2 26 ,,	186			
							1 16 Oct. '11	206			
							1 15 Nov. '11	236			
							1 7 Dec. '11	258			
							1 25 ,,	276			
23 March '11	15	Beehive	March	52·5	33·3	—	1 9 May '11	47	124	6 %	1 cocoon opened 30 Sept. '11 contained living flea Remaining cocoon contained dead flea
			April	61·7	36·8	—	2 13 ,,	51			
			May	72·8	45·2	—	1 18 ,,	58			
			June	73·0	56·5	—	1 30 ,,	68			
			July	80·3	58·6	—	1 14 June '11	83			
			Aug.	80·2	57·6	—	1 14 July '11	113			
			Sept.	75·3	48·0	—	1 24 ,,	123			
							1 2 Aug. '11	132			
							1 25 Sept. '11	186			
							1 30 ,,	191			
							1 3 Oct.	194			
							1 27 ,,	218			
							1 4 Nov.	226			
				Dry							
24 March '11	15	Warm cupboard	March	61·7		·58	3 7 April '11	14	31	Nil	Remaining cocoons opened 30 Sept. '11 empty. ? "false" cocoon
			April	63·0		·57	2 9 ,,	16			
			May	62·9		·60	1 10 ,,	17			
							1 11 ,,	18			
							1 15 ,,	22			
							1 17 ,,	24			
							2 23 May '11	60			
							1 24 ,,	61			
							1 30 ,,	67			

Table XXXI (*c*). *Cocoons* C. fasciatus. *Full grown larvae taken from the breeding cages and allowed to spin in Incubator* 75 *Wet* (*Temperature* 73° *F., Humidity* ·70); *cocoons also maintained in Incubator* 75 *Wet.*

Contrast between cocoons kept in card jar and tube.

Date on which the cocoons were placed under test conditions	Number of cocoons	Receptacle	Temperature	Humidity	Dates of emergence of fleas	Number of days in cocoon	Average	Mortality	Remarks
20 Feb. '11	15	Tube	74·6	·77	1 1 March '11	9	37	27 %	Remainder of cocoons opened 17 Aug. '11, found 1 dried up pupa, 3 dried up larvae
					2 2 ,,	10			
					2 4 ,,	12			
					2 13 April '11	52			
					1 15 ,,	54			
					1 21 ,,	60			
					1 24 ,,	63			
					1 2 May '11	71			
,,	15	Jar	74·6	·77	2 28 Feb. '11	8	41	20 %	Remainder of cocoons opened 18 Aug. '11, found 1 dried up flea, 2 dried up larvae
					1 1 March '11	9			
					1 4 ,,	12			
					3 10 April '11	49			
					1 15 ,,	54			
					1 20 ,,	59			
					1 21 ,,	60			
					1 24 ,,	63			
					1 30 ,,	69			

TABLE XXXII. Cocoons C. fasciatus. *Full grown larvae taken from breeding cages and sorted into batches; these allowed to spin under one set of conditions and transferred to contrasting conditions for the cocoon stage.*

Date on which the larvae were taken from the breeding cages	No. of larvae	Place in which the larvae formed their cocoons and dates on which they were found and transferred	Temp. max. min.	Humidity	Place to which the cocoons were transferred and dates of emergence of fleas	Temp.	Humidity	Estimated no. of days in cocoon	Average	Mortality
11 Nov. '10	18	Cellar	47·6 46·2	·92	Incubator 85 Wet*	84·1	·70	1 took 9 days	77	Nil
		2 16 Nov. '10			1 25 Nov. '10			1 ,, 14		
		1 18 ,,			3 6 Dec. '10			1 ,, 18		
		3 22 ,,			1 16 Jan. '11			1 ,, 20		
		4 25 ,,			1 15 Feb. '11			1 ,, 55		
		2 28 ,,			1 20 ,,			1 ,, 85		
		5 1 Dec. '10			1 23 ,,			1 ,, 87		
					1 26 ,,			1 ,, 90		
					2 28 ,,			2 ,, 92		
					1 2 March '11			1 ,, 93		
					1 3 ,,			1 ,, 94		
					2 16 ,,			1 ,, 95		
					1 17 ,,			2 ,, 105		
					2 25 ,,			1 ,, 106		
								2 ,, 114		
						max. min.				
8 Nov. '10	13	Incubator 85 Wet	84·1	·70	Cellar	Nov. 48·6 47·1	·92	5 took 51	111	Nil
		9 9 Nov. '10			5 30 Dec. '10	Dec. 50·9 48·8	·93	1 ,, 53		
		4 11 ,,			1 2 Jan. '11	Jan. 46·5 45·3	·92	1 ,, 59		
					1 8 ,,	Feb. 46·4 44·8	·92	1 ,, 60		
					1 9 ,,	Mar. 46·5 45·3	·91	1 ,, 63		
					1 12 ,,	Apr. 48·5 46·6	·91	1 ,, 68		
					1 19 ,,	May 53·9 52·6	·92	1 ,, 236		
					1 5 July '11	June 58·1 56·7	·93	1 ,, 319		
					1 25 Sept. '11†	July 61·6 60·4	·93	1 ,, 328		
					1 5 Oct. '11	Aug. 64·5 63·4	·94			
						Sept. 60·6 59·5	·93			
6 Nov. '10	19	Laboratory cupboard	54·0 42·8	·84	Incubator 75 Wet	74·3	·75	4 took 11	30	Doubtful
		3 7 Nov. '10			3 18 Nov. '10			4 ,, 14		
		1 8 ,,			2 22 ,,			1 ,, 34		
		2 11 ,,			1 25 ,,			1 ,, 57		
		4 13 ,,			2 27 ,,			3 ,, 67		
		3 15 ,,			1 17 Dec. '10					
		3 17 ,,			1 9 Jan. '11					
		2 23 ,,			3 21 ,,					
		1 28 ,,			(6 cocoons opened 7 June '11 were empty in some cases, in others contained dried up larvae)					
28 Oct. '10	18	Incubator 75 Wet	73·9	·74	Laboratory cupboard	55·5 46·4	·85	3 took 26	33	6 %
		18 2 Nov. '10			3 28 Nov. '10			7 ,, 34		
					7 6 Dec. '10			3 ,, 36		
					3 8 ,,			1 ,, 43		
					1 15 ,,			2 ,, 47		
					2 19 ,,					
					(2 cocoons opened 9 June; 1 empty, 1 contained dried pupa)					

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* 18 fleas emerged from 17 cocoons, the inference is that two cocoons were spun together.

† Cocoon opened, living flea emerged.

11 Apr. '11	26	Cellar 1 13 April '11 3 17 ,, 9 22 ,, 3 25 ,, 1 27 ,, 2 23 May '11 5 27 ,, 1 8 June '11 1 26 ,,	55·1 53·5	·92	Incubator 85 Dry 1 4 May '11 1 6 June '11 1 26 July '11 2 2 Aug. '11 1 17 ,, 1 4 Sept. '11	84·0	·63	1 took 21 1 ,, 50 1 ,, 100 1 ,, 102 1 ,, 107 1 ,, 117 1 ,, 135	90	73 %
					(19 cocoons opened 23 Oct. '11 contained 1 dried up flea, 1 dried up pupa, 17 dried up larvae)					
,,	26	Incubator 85 Dry 4 13 April '11 4 15 ,,	84·0	·60	Cellar 1 27 May '11 1 3 June '11 1 26 ,, 1 27 July '11 2 1 Aug. '11 1 26 Sept. '11	max. min. Apr. 48·5 44·6 May 53·9 52·6 June 58·1 56·7 July 61·6 60·4 Aug. 64·5 63·4 Sept. 60·6 59·5	·91 ·92 ·93 ·93 ·94 ·93	1 took 44 1 ,, 51 1 ,, 74 1 ,, 105 2 ,, 108 1 ,, 133	89	Nil
		(2 larvae emerged from their cocoons and one died, the remainder died without spinning)								
,,	26	Laboratory cupboard 3 18 April '11 2 19 ,, (Remainder of larvae died)	59·2 46·6	·77	Incubator 75 Dry	75·0	·50	—	—	100 %
					(Cocoons opened 28 Sept. '11 contained dried up larvae)					
,,	26	Incubator 75 Dry (Larvae all died without spinning)	76·0	·49	—	—	—	—	—	—
						(No cocoons to transfer)				
,,	26	Warm cupboard (Larvae all died without spinning)	62·3	·54	—	—	—	—	—	—
						(No cocoons to transfer)				
,,	26	Incubator 75 Wet 12 13 April '11 3 15 ,, 1 16 ,, 1 12 May '11 2 15 ,,	75·2	·80	Warm cupboard 2 26 April '11 1 2 May '11 1 29 ,, 1 2 June '11	Apr. 63·0 May 62·9 June 66·6	·57 ·60 ·65	2 took 13 1 ,, 19 1 ,, 46 1 ,, 50	28	58 %
		(2 larvae emerged from cocoons before transference)			(13 cocoons opened 30 Sept. '11 contained 9 dried up larvae, 1 dried up pupa, 2 empty "false" cocoons)					
,,	26	Incubator 85 Wet 11 12 April '11 8 13 ,,	84·6	·72	Beehive 7 13 May '11 4 23 ,, 2 26 ,, 2 10 June '11 2 14 ,, 1 24 ,, 1 2 Aug. '11	74·1 49·6 (Averages)	—	7 took 31 4 ,, 41 2 ,, 43 2 ,, 58 2 ,, 62 1 ,, 72 1 ,, 111	47	Nil
		(Remainder of larvae lost owing to accident)								

TABLE XXXII.—*Continued.* *Cocoons* C. fasciatus.

Date on which the larvae were taken from the breeding cages	No. of larvae	Place in which the larvae formed their cocoons and dates on which they were found and transferred	Temp. max. min.	Humidity	Place to which the cocoons were transferred and dates of emergence of fleas	Temp.	Humidity	Estimated no. of days in cocoon	Av.	Mortality
11 Apr. '11	26	Beehive	69·6 33·3	—	Incubator 85 Wet	83·0	·76	—	—	—
		1 19 April '11				(No emergence from cocoon)				
		(25 larvae died)								
						1911 max. min.				
*3 June '11	Unre-corded	Incubator 85 Wet	76·4	·93	Cellar	June 58·1 56·7	·93		88	Nil
		22 6 June '11			3 5 July '11	July 61·6 60·4	·93	3 took 24		
					1 12 ,,	Aug. 64·5 63·4	·94	1 ,, 36		
					1 27 ,,	Sept. 60·6 59·5	·93	1 ,, 51		
					1 1 Aug. '11	Oct. 56·3 54·8	·92	1 ,, 56		
					2 9 ,,	Nov. 50·7 48·9	·91	2 ,, 64		
					1 11 ,,	Dec. 48·7 47·4	·92	1 ,, 66		
					3 21 ,,	1912		3 ,, 76		
					1 11 Sept. '11	Jan. 47·2 45·9	·92	1 ,, 97		
					1 14 ,,	Feb. 45·8 44·6	·92	1 ,, 100		
					2 19 ,,	Mar. 49·1 48·1	·93	2 ,, 105		
					1 26 ,,	Apr. 50·3 49·1	·93	1 ,, 112		
					1 16 Oct. '11			1 ,, 132		
					1 1 Nov. '11			1 ,, 148		
					1 15 ,,			1 ,, 162		
					1 20 ,,			1 ,, 167		
					1 7 Dec. '11			1 ,, 184		
* ,,	Unre-corded	Incubator 75 Wet	1911		Cellar	(as above)			91	about 3 %
		14 6 June '11	June 75·8	·86	3 5 July '11			3 took 29		
		17 8 ,,			4 12 ,,			4 ,, 36		
					3 11 Aug. '11			3 ,, 66		
					2 21 ,,			2 ,, 76		
					1 11 Sept. '11			1 ,, 97		
					3 14 ,,			2 ,, 98		
					4 19 ,,			1 ,, 100		
					1 26 ,,			4 ,, 103		
					2 5 Oct. '11			1 ,, 110		
					1 16 ,,			2 ,, 119		
					1 1 Nov. '11			1 ,, 130		
					1 9 ,,			1 ,, 146		
					1 26 April '12			1 ,, 154		
								1 ,, 323		

(Remaining cocoons opened contained 1 dead flea, 3 false cocoons)

TABLE XXXIII. *Cocoons* C. fasciatus. *Monthly test. June* 1911 *to February* 1912. *Full grown larvae taken from the breeding cages and allowed to spin in Incubator* 75 *Wet; cocoons then removed to various situations.*

Incubator 75 Wet.

Date on which the cocoons were placed under test conditions	Number of cocoons	Temperature	Humidity	Min. days in cocoon	Max. days in cocoon	Average number of days in cocoon	Number of fleas emerging	Mortality	Remarks
17 June '11	26	June 75·8	·86	10	59	16	26	Nil	—
11 July '11	22	July 76·3	·85	13	72	42	21	Nil	1 "false" cocoon
15 Aug. '11	22	Aug. 75·0	·80	13	59	24	21	Nil	,, ,,
20 Sept. '11	22	Sept. 74·8	·76	12	54	27	18	10 %	as larvae, 2 "false" cocoons
20 Oct. '11	22	Oct. 74·4	·73	11	57	25	17	14 %	as fleas, 2 "false" cocoons
15 Nov. '11	22	Nov. 75·0	·69	10	82	31	22	Nil	—
10 Dec. '11	22	Dec. 75·8	·65	9	64	15	18	18 %	9 % as larvae, 9 % as fleas
5 Jan. '12	22	1912		15	58	22	21	Nil	1 "false" cocoon
11 Feb. '12	22	Jan. 75·5	·71	8	79	27	20	5 %	as flea, 1 "false" cocoon
		Feb. 75·0	·76						
		Mar. 75·1	·79						
		April 75·8	·79						
		May 75·6	·86						
		June 74·9	·83						
		July 75·0	·86						
		Aug. 74·3	·81						
Incubator 75 Dry.									
17 June '11	22	June 75·2	·53	9	27	15	20	10 %	as larvae
11 July '11	22	July 76·3	·57	13	70	31	4	72 %	,, 2 "false" cocoons
14 Aug. '11	22	Aug. 75·7	·59	11	23	14	22	Nil	—
18 Sept. '11	22	Sept. 74·9	·54	10	45	18	14	27 %	22 % as larvae, 5 % as fleas, 2 "false" cocoons
20 Oct. '11	22	Oct. 74·6	·52	11	60	24	19	Nil	3 "false" cocoons
16 Nov. '11	22	Nov. 74·4	·54	11	68	28	6	72 %	as larvae
12 Dec. '11	22	Dec. 74·7	·51	12	70	24	20	9 %	,,
4 Jan. '12	22	1912		8	128*	34	20	9 %	,,
11 Feb. '12	22	Jan. 75·2	·50	11	86	36	17	14 %	,,
		Feb. 73·5	·56						
		Mar. 73·2	·56						
		April 74·1	·56						
		May 74·7	·59						
		June 75·8	·54						
		July 76·2	·64						
		Aug. 75·0	·56						

* A cocoon opened on the 11th May contained a living flea.

TABLE XXXIII.—*Continued.*

Incubator 85/93 Dry.

Date on which the cocoons were placed under test conditions	No. of cocoons	Temperature	Humidity	Min. days in cocoon	Max. days in cocoon	Average number of days in cocoon	Number of fleas emerging	Mortality	Remarks
19 June '11	28	June 83·9	·60	8	117	32	16	43%	4% fleas, 39% larvae
19 July '11	22	July 84·3	·64	14	92	48	14	36%	31% larvae, 5% fleas
14 Aug. '11	22	Aug. 83·8	·63	14	66	23	15	say 9%	1 dead flea, 1 dead larva, 5 empty cocoons, doubtful if "false" cocoons or larval remains past recognition
		Sept. 84·4	·59						
		Oct. 84·7	·60						
21 Sept. '11	22	Nov. 92·9	·56	11	40	17	17	10%	5% larvae, 5% fleas, 3 "false" cocoons
20 Oct. '11	22	Dec. 92·8	·57	18	24	21	13	30%	10% fleas, 20% larvae, 3 "false" cocoons. 2 cocoons opened 16 March contained living but somewhat shrunken larvae which subsequently died
		1912							
		Jan. 93·2	·56						
		Feb. 93·0	·60						
14 Nov. '11	22	Mar. 93·1	·60	1 flea emerged in 7 days		7	1	72%	2 larvae emerged from cocoons 20 Nov. and died; cocoons opened 16 March contained 11 dead and dried larvae, 1 doubtful if dead as it still retained its natural colour and appearance but did not move, 2 dead fleas, remainder "false" cocoons
		Apr. 93·7	·61						
		May 93·3	·58						
		June 93·0	·55						
		July 93·0	·57						
		Aug. 93·0	·54						
12 Dec. '11	22			10	118	77	11	doubtful	cocoons examined 16 March '12; 4 opened contained 3 resting larvae*, 1 empty; the remaining cocoons and 3 extracted larvae were transferred to Incubator 75 Wet and 6 fleas emerged; on 31 May 1912 a cocoon opened contained a dead flea
13 Feb. '12	22			—	—	—	—	100%	cocoons opened 28 June contained 8 dried up larvae, 5 dried up pupae, 9 dried up fleas
Incubator 85/93 Wet.									
19 June '11	28	June 84·0	·80	8	74	19	25	10%	as larvae
19 July '11	22	July 85·1	·83	12	105	42	19	15%	5% as larvae, 10% as fleas
14 Aug. '11	22	Aug. 84·7	·81	7	42	28	17	22%	as fleas
20 Sept. '11	22	Sept. 84·8	·77	7	30	13	15	5%	as pupae
20 Oct. '11	22	Oct. 84·5	·78	13	31	15	18	10%	5% as fleas, 5% as larvae; 2 cocoons opened 11 May '12 contained resting larvae (204 days); they were transferred to Incubator 75 Wet with 1 unopened cocoon; the resting larvae died, the cocoon was opened 12 June and found to contain a dead larva
		Nov. to 23rd 85·2	·73						
		Nov. to 30th 75·0	·69						
		Dec. 92·4	·66						
		1912							
		Jan. 92·6	·66						
15 Nov. '11	22	Feb. 92·4	·68	10	28	14	6	69%	5% as fleas, 5% as pupae, 59% as larvae
12 Dec. '11	22	Mar. 92·3	·67	7	25	14	9	50%	23% as fleas, 9% as pupae, 18% as larvae; 2 resting larvae taken from their cocoons after 203 days were transferred to Incubator 75 Wet but died
		April 93·1	·69						
		May 95·1	·75						
		June 94·5	·77						

6 Jan. '12	22	July	95·2		·74	12	24	14	12	41 %	23 % as fleas, 4 % as pupae, 14 % as larvae; 2 of the larvae though shrunken were still fresh and natural in appearance as though but recently dead
		Aug.	94·2		·75						
11 Feb. '12	22					9	72	28	4	68 %	23 % as fleas, 4 % as pupae, 41 % as larvae; 3 of these larvae though shrunken were still fresh and natural in appearance as though but recently dead

Warm Cupboard.

17 June '11	22	June	66·6		·65	11	62	21	—	Nil	—
10 July '11	22	July	71·3		·65	14	68	54		72 %	4 % as fleas, 68 % as larvae
14 Aug. '11	22	Aug.	75·0		·66	14	56	25		27 %	as larvae
16 Sept. '11	22	Sept.	66·3		·66	14	141	33		5 %	,,
23 Oct. '11	22	Oct.	67·4		·59	14	98	31		14 %	,,
13 Nov. '11	22	Nov.	63·0		·58	18	91	43		64 %	5 % as fleas, 59 % as larvae, 1 "false" cocoon
11 Dec. '11	22	Dec.	62·3		·62	10	17	·12		9 %	as larvae, 2 "false" cocoons
4 Jan. '12	22	1912				14	78	26		18 %	,, ,, ,,
19 Feb. '12	22	Jan.	59·7		·60	14	108	25		14 %	,, 1 "false" cocoon
		Feb.	59·5		·63						
		Mar.	60·7		·59						
		April	59·0		·64						
		May	62·6		·70						
		June	65·0		·73						
		July	67·3		·71						
		Aug.	64·5		·71						

Laboratory Cupboard.

			max.	min.							
15 June '11	22	June	66·4	58·2	·79	23	83	42	—	Nil	—
10 July '11	22	July	71·5	62·7	·75	23	218	74		Nil	—
11 Aug. '11	22	Aug.	72·0	64·1	·74	19	73	37		9 %	as larvae
15 Sept. '11	22	Sept.	65·7	55·7	·77	24	350	73		9 %	1 larva emerged from cocoon and died; 1 dead flea found in cocoon; 1 resting larva taken from cocoon after 357 days
		Oct.	59·0	50·9	·84						
		Nov.	54·9	46·1	·85						
20 Oct. '11	22	Dec.	53·9	46·2	·87	32	222	64		5 %	as larvae; 1 resting larva taken from cocoon
13 Nov. '11	22	1912				39	352	261		5 %	as larvae
11 Dec. '11	22	Jan.	52·5	44·9	·89	24	257	101		9 %	as fleas, died in cocoons; 1 living pupa taken from cocoon after 270 days
		Feb.	54·4	45·3	·86						
4 Jan. '12	22	Mar.	56·0	47·8	·76	44	107	59		5 %	as flea, died in cocoon; 1 living pupa taken from cocoon after 246 days, 1 resting larva taken from cocoon after 246 days
		April	60·6	50·4	·83						
		May	64·0	56·8	·87						
21 Feb. '12	22	June	64·6	58·3	·81	36	198	67		Nil	1 living flea taken from cocoon after 198 days, 1 living pupa taken from cocoon after 198 days
		July	68·5	62·1	·79						
		Aug.	63·3	56·3	·84						

* One of the extracted larvae pupated on the 27th March '12 and the flea emerged on the 3rd April '12.

NOTE. Mortality "as fleas" implies that death occurred in cocoons.

TABLE XXXIII.—*Continued.*

Date on which the cocoons were placed under test conditions	No. of cocoons		Temperature max.	Temperature min.	Humidity	Min. days in cocoon	Max. days in cocoon	Average number of days in cocoon	Mortality	Remarks
					Beehive.					
17 June '11	22	June	73·0	56·5	—	23	97	37	Nil	4 "false" cocoons
10 July '11	22	July	80·3	58·6	—	14	82	37	30 %	25 % died as larvae, 5 % died as pupa, 2 "false" cocoons
		Aug.	80·2	57·6	—					
11 Aug. '11	22	Sept.	75·3	48·0	—	17	45	34	30 %	died as larvae, 2 "false" cocoons
15 Sept. '11	22	Oct.	61·9	41·3	—	28	75	40	Nil	1 resting larva found on opening cocoons on 22 June '12 living after 272 days, it died without pupating
		Nov.	49·0	34·7	—					
		Dec.	46·8	35·0	—					
23 Oct. '11	22	1912				74	319	125	Nil	1 resting larva taken from cocoon after 255 days, 1 living flea taken from cocoon after 319 days
		Jan.	43·6	34·0	—					
		Feb.	46·9	34·3	—					
13 Nov. '11	22	Mar.	54·1	38·2	—	99	324	196	5 %	as flea; 1 living larva taken from cocoon after 234 days, 1 living larva taken from cocoon after 298 days, 1 living pupa taken from cocoon after 298 days, 1 living flea taken from cocoon after 298 days
		April	64·1	37·3	—					
		May	67·9	47·3	—					
		June	67·7	49·9	—					
		July	73·4	55·4	—					
11 Dec. '11	22	Aug.	64·9	45·6	—	33	180	98	Nil	—
4 Jan. '12	22					86	246	117	23 %	9 % larvae, 5 % pupa, 9 % fleas; 1 living flea taken from cocoon on 6 Sept., 1 living pupa taken from cocoon on 6 Sept.
24 Feb. '12	22					45	195	92	Nil	1 living larva taken from cocoon after 517 days
					Cellar.					
15 June '11	22	June	58·1	56·7	·93	27	109	49	Nil	—
10 July '11	22	July	61·6	60·4	·93	22	390	78	Nil	1 resting larva found in cocoon after 348 days, 1 resting larva found in cocoon after 424 days
		Aug.	64·4	63·4	·94					
		Sept.	60·6	59·5	·93					
11 Aug. '11	22	Oct.	56·3	54·8	·92	17	122	33	4 %	as flea
15 Sept. '11	22	Nov.	50·7	48·9	·91	31	329	88	10 %	5 % as larva, 5 % as pupa; 1 resting larva from very hard cocoon after 281 days, 1 living pupa after 358 days
		Dec.	48·7	47·4	·92					
		1912								
23 Oct. '11	22	Jan.	47·2	45·9	·92	35	119	57	5 %	as larva; 1 resting larva from cocoon after 243 days, 1 living pupa from cocoon after 320 days
		Feb.	45·8	44·6	·92					
		Mar.	49·1	48·1	·93					
13 Nov. '11	22	April	50·3	49·1	·93	53	450	296	9 %	2 dead larvae, 1 living larva taken from cocoon after 222 days
		May	54·2	53·2	·93					
11 Dec. '11	22	June	56·4	55·6	·93	35	303	131	5 %	1 dead larva, 2 living fleas taken from cocoon after 271 days
		July	60·1	59·3	·93					
4 Jan. '12	22	Aug.	57·5	56·5	·93	63	247	92	Nil	1 living flea extracted from cocoon after 247 days
19 Feb. '12	22					37	245	83	Nil	2 living pupae taken from cocoons after 201 days

NOTE. Mortality "as fleas" implies that death occurred in cocoons.

TABLE XXXIV. *Cocoons* X. cheopis. *"Continuous series*," each batch maintained during larval and cocoon stage in the same situation.*

Date of commencement of experiment in larval stage	Number of cocoons found	Temperature			Humidity	Approximate duration of cocoon stage		Average number of days in cocoon	Mortality in cocoon stage	Food	Remarks
			max.	min.		No. of cocoons	Days				
						Cellar.					
6 June '11	2	Aug.	64·5	63·4	·94	1	147	—	50 %	B.S. Rag	Second cocoon opened contained dried up flea
3 July '11	13	Sept.	60·6	59·5	·93	1	41	90	30 %	Flea faeces	Remaining cocoons opened 3 July '12 contained 4 dried up fleas, 1 "false" cocoon
		Oct.	56·3	54·8	·92	3	68				
		Nov.	50·7	48·9	·91	1	77				
		Dec.	48·7	47·4	·92	1	96				
						1	114				
						1	191				
,,	14		—		—	3	34	69	14 %	Rat faeces crushed	Remaining cocoons opened 3 July '12 contained 1 dried up flea, 1 dried up larva, 1 "false" cocoon
						2	41				
						1	50				
						2	91				
						1	96				
						1	114				
						1	128				
						Incubator 85 Wet.					
11 Aug. '11	12		84·8		·78	7	11	13	Nil	B.S. Rag	—
						4	15				
						1	18				
,,	7		84·8		·78	1	7	12	Nil	Flea faeces	—
						3	11				
						3	15				
4 Sept. '11	22		84·7		·78	1	9	13	Nil	B.S. Rag	2 cocoons opened and found to be empty ("false" cocoons)
						2	11				
						1	12				
						9	14				
						5	15				
						2	18				
						Incubator 75 Wet.					
,,	21		74·7		·70	1	16	22	Nil	,,	2 cocoons opened after 46 days contained living fleas
						4	17				
						7	19				
						5	20				
						2	24				
						2	46				

* Experiments in Table XXXIV are in direct continuity with those dealing with the larval series in Table XX.

TABLE XXXV. *Cocoons* X. Cheopis. *Full grown larvae taken from the cages and allowed to spin in Incubator 75 Wet (Temp. 76° F., Humidity ·84); cocoons then placed in different situations.*

NOTE. Experiments on the same date are from the same batch of cocoons.

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature			Humidity	Date of emergence of fleas	Duration of cocoon stage No. of cocoons	Days	Aver. days	Mortality per cent.	Remarks
				max.	min.							
16 June '11	14	Cellar	June	58·1	56·7	·93	1 on 16 Aug.	1	61	93	35	Cocoons opened, 5 dead fleas
			July	61·6	60·4	·93	3 ,, 21 ,,	3	66			
			Aug.	64·5	63·4	·94	1 ,, 5 Sept.	1	81			
			Sept.	60·6	59·5	·93	1 ,, 14 ,,	1	90			
			Oct.	56·3	54·8	·92	1 ,, 20 ,,	1	96			
			Nov.	50·7	48·9	·91	1 ,, 11 Nov.	1	148			
			Dec.	48·7	47·4	·92	1 ,, 2 Dec.	1	169			
,, ,,	14	Lab. Cupboard	June	66·4	58·2	·79	1 ,, 21 July	1	35	65	21	3 cocoons opened 21 Oct. contained 1 larva died in pupation, 1 dried up flea, 1 dried up pupa
			July	71·5	62·7	·75	1 ,, 27 ,,	1	41			
			Aug.	72·0	64·1	·74	1 ,, 2 Aug.	1	47			
			Sept.	65·7	55·7	·77	1 ,, 9 ,,	1	54			
							2 ,, 16 ,,	2	71			
							4 ,, 30 ,,	4	75			
							1 ,, 22 Sept.	1	98			
19 ,,	14	Warm Cupboard		69·8		·66	2 ,, 10 July	2	21	29	14	2 cocoons opened 24 Oct. contained 1 dried up flea, 1 dried up larva
							1 ,, 13 ,,	1	24			
							2 ,, 15 ,,	2	26			
							3 ,, 17 ,,	3	28			
							3 ,, 26 ,,	3	37			
							1 ,, 31 ,,	1	42			
,, ,,	13	Beehive	June	73·0	56·5	—	1 ,, 14 ,,	1	25	35	Nil	—
			July	80·3	58·6		2 ,, 18 ,,	2	29			
			Aug.	80·2	57·6		6 ,, 24 ,,	6	35			
							3 ,, 29 ,,	3	40			
							1 ,, 2 Aug.	1	44			
21 ,,	16	Incubator 75 Dry		76		·57	2 ,, 5 July	2	14	22	50	8 cocoons opened 23 Oct. contained 2 dried up pupae, 6 dried up larvae
							2 ,, 10 ,,	2	19			
							2 ,, 11 ,,	2	20			
							1 ,, 13 ,,	1	22			
							1 ,, 8 Aug.	1	48			
26 ,,	14	,, 75 Wet		76·1		·86	7 ,, 10 July	7	14	15	Nil	2 cocoons opened 2 Oct. and found to be empty ("false" cocoons)
							2 ,, 11 ,,	2	15			
							2 ,, 13 ,,	2	17			
							1 ,, 17 ,,	1	21			

,, ,,	14	,,	85 Wet	84·2	·81	1 ,, 5 ,,	1	9	12	7	3 cocoons opened 2 Oct. contained 1 dried up flea, 2 empty ("false" cocoons)
						3 ,, 6 ,,	3	10			
						1 ,, 7 ,.	1	11			
						2 ,, 10 ,,	2	14			
						4 ,, 11 ,,	4	15			
,, ,,	14	,,	85 Dry	84·4	·66	1 ,, 3 ,,	1	7	13	7	3 cocoons opened 23 Oct. contained 1 dried up flea, 2 empty ("false" cocoons)
						3 ,, 5 ,,	3	9			
						1 ,, 7 ,,	1	11			
						3 ,, 11 ,,	3	15			
						3 ,, 13 ,,	3	17			
8 Aug. 11	47	Cellar		max. min. Aug. 64·5 63·4	·94	2 ,, 5 Sept.	2	28	70	10	Cocoons opened, 5 dead fleas, 2 "false" cocoons
				Sept. 60·6 59·5	·93	8 ,, 11 ,,	8	34			
				Oct. 56·3 54·8	·92	3 ,, 14 ,,	3	37			
				Nov. 50·7 48·9	·91	2 ,, 20 ,,	2	43			
				Dec. 48·7 47·4	·92	6 ,, 26 ,,	6	49			
						3 ,, 5 Oct.	3	58			
						2 ,, 1 Nov.	2	85			
						2 ,, 9 ,,	2	93			
						3 ,, 15 ,,	3	99			
						2 ,, 20 ,,	2	104			
						1 ,, 27 ,,	1	111			
						1 ,, 7 Dec.	1	121			
						1 ,, 11 ,,	1	125			
						2 ,, 22 ,,	2	136			
						1 ,, 4 Jan.	1	149			
						1 ,, 15 ,,	1	160			
,, ,,	47	Beehive		Aug. 80·2 57·6	—	5 ,, 22 Aug.	5	14	23	51	1 larva emerged from cocoon and died; cocoons opened, 1 dead flea, 3 dead pupae, 19 dead larvae, remaining cocoons empty (i.e. "false" cocoons)
				Sept. 75·3 48·0		1 ,, 28 ,,	1	20			
				Oct. 61·9 41·3		2 ,, 2 Sept.	2	25			
						1 ,, 6 ,,	1	29			
						4 ,, 9 ,,	4	32			
,, ,,	47	Lab. Cupboard		Aug. 72·0 64·1	·74	2 ,, 6 Sept.	2	29	60	30	Remaining cocoons opened 2 July '12, 3 dead fleas, 3 dead pupae, 8 dead larvae, 4 "false" cocoons
				Sept. 65·7 55·7	·77	2 ,, 9 ,,	2	32			
				Oct. 59·0 50·9	·84	1 ,, 12 ,,	1	35			
				Nov. 54·9 46·1	·85	1 ,, 22 ,,	1	45			
				Dec. 53·9 46·2	·87	2 ,, 26 ,,	2	49			
						1 ,, 30 ,,	1	53			
						1 ,, 9 Oct.	1	62			
						3 ,, 13 ,,	3	66			
						7 ,, 20 ,,	7	73			
						2 ,, 21 ,,	2	74			
						1 ,, 11 Nov.	1	95			
						1 ,, 27 ,,	1	111			
						2 ,, 16 Dec.	2	130			
						1 ,, 29 ,,	1	143			
						1 ,, 31 Jan.	1	176			
						1 ,, 6 Feb.	1	182			

TABLE XXXV.—*Continued.*

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature	Humidity	Date of emergence of fleas	Duration of cocoon stage No. of cocoons	Days	Aver. days	Mortality per cent.	Remarks
23 Sept. '11	22	Incubator 85 Wet	85·1	·77	4 on 7 Oct.	4	14	16	14	14 cocoons opened contained 2 dead fleas, 1 dead larva, 11 empty, "false" cocoons
					3 ,, 10 ,,	3	17			
					1 ,, 14 ,,	1	21			
,, ,,	22	,, 85 Dry	85	·59	1 ,, 2 ,,	1	9	15	?Nil	Remaining cocoons empty, "false" cocoons, no cast skin
					7 ,, 5 ,,	7	12			
					3 ,, 19 ,,	3	26			
25 ,,	22	,, 75 ,,	74·6	·52	4 ,, 14 ,,	4	19	25	45	4 larvae emerged from their cocoons and died at start; 6 cocoons opened 23 Oct. contained 5 dried up larvae, 1 dried up flea
					4 ,, 19 ,,	4	24			
					2 ,, 23 ,,	2	28			
					2 ,, 31 ,,	2	36			
,, ,,	22	,, 75 Wet	75	·70	8 ,, 14 ,,	8	19	28	Nil	3 "false" cocoons found
					7 ,, 19 ,,	7	24			
					2 ,, 24 ,,	2	29			
					1 ,, 5 Dec.	1	71			
					1 ,, 28 ,,	1	94			
1 Dec. '11	22	,, 93 ,,	92·3	·67	6 ,, 11 ,,	6	10	13	9	Cocoons opened 11 May '12, 2 dead fleas
					2 ,, 13 ,,	2	12			
					6 ,, 16 ,,	6	15			
					1 ,, 19 ,,	1	18			
4 ,,	22	,, 93 Dry	92·8	·57	5 ,, 13 ,,	5	9	13	18	Cocoons opened 16 March '12, 4 dead fleas
					2 ,, 16 ,,	2	12			
					7 ,, 19 ,,	7	15			
					1 ,, 22 ,,	1	18			
,, ,,	22	,, 75 Wet	75·8	·65	2 ,, 16 ,,	2	12	17	5	Cocoons opened 5 Sept. '12, 1 dead flea, 3 empty ("false" cocoons)
					5 ,, 19 ,,	5	15			
					1 ,, 22 ,,	1	18			
					7 ,, 23 ,,	7	19			
					1 ,, 24 ,,	1	20			
					2 ,, 25 ,,	2	21			
,, ,,	22	,, 75 Dry	74·7	·51	5 ,, 16 ,,	5	12	15	27	One larva came out of cocoon and died; cocoons opened 11 May '12, 6 dead larvae
					3 ,, 19 ,,	3	15			
					1 ,, 22 ,,	1	18			
					2 ,, 25 ,,	2	21			
,, ,,	22	Warm Cupboard	Dec. 62·3 Jan. 59·7	·62 ·60	1 ,, 22 ,,	1	18	25	36	Cocoons opened 4 July '12, 8 dried up fleas, 1 "false" cocoon
					3 ,, 24 ,,	3	20			
					4 ,, 25 ,,	4	21			
					3 ,, 4 Jan.	3	31			
					1 ,, 8 ,,	1	35			
					1 ,, 15 ,,	1	42			

7 ,,	22	Beehive	max min. Dec. 46·8 35·0 Jan. 43·6 34·0 Feb. 46·9 34·3	—	None emerged	—	—	—	100	2 larvae came out of their cocoons and died; cocoons opened 4 July '12 contained 18 dried up larvae, 2 "false" cocoons
,, ,,	22	Cellar	Dec. 48·7 47·4 Jan. 47·2 45·9 Feb. 45·8 44·6	·92 ·92 ·92	None emerged	—	—	—	100	Cocoons opened 5 July '12 contained 19 dried up larvae, 3 "false" cocoons
,, ,,	22	Lab. Cupboard	Dec. 53·9 46·2 Jan. 52·5 44·9	·87 ·89	None emerged	—	—	—	100	2 larvae came out of their cocoons and died; cocoons opened 3 July '12, 1 dried up pupa, 19 dried up larvae
6 April '12	22	Incubator 93 Dry	93·7	·63	2 on 15 April 1 ,, 20 ,, 2 ,, 22 ,,	2 1 2	9 14 16	13	27	Remaining cocoons opened 6 Sept., 2 dead fleas, 4 dead larvae, 15 empty (11 "false" cocoons)
9 ,,	23	,, 93 Wet	93·1	·70	3 ,, 18 ,, 4 ,, 20 ,, 7 ,, 23 ,, 1 ,, 25 ,,	3 4 7 1	9 11 14 16	12	30	Remaining cocoons opened 4 Sept., 2 dead fleas, 1 dead pupa, 4 dead larvae (1 "false" cocoon)
12 ,,	22	,, 75 ,,	April 75·8 May 75·6 June 74·9	·79 ·86 ·83	11 ,, 27 ,, 2 ,, 30 ,, 4 ,, 6 May 1 ,, 10 ,, 1 ,, 28 June	11 2 4 1 1	15 18 24 28 77	21	5	Remaining cocoons opened 5 Sept., 1 dead flea (2 "false" cocoons)
13 ,,	22	,, 75 Dry	April 74·1 May 74·7	·56 ·59	None emerged	—	—	—	100	4 larvae came out of cocoons and died; remaining cocoons opened 5 Sept., 17 dead larvae (1 "false" cocoon)
,, ,,	22	Cellar	max. min. April 50·3 49·1 May 54·2 53·2	·93 ·93	None emerged	—	—	—	100	Cocoons opened 5 July '12, 19 dried up larvae, 3 "false" cocoons
15 ,,	22	Lab. Cupboard	April 60·6 50·4 May 64·0 56·8	·83 ·87	1 on 25 May	1	40	—	95	Remaining cocoons opened 6 July '12, 16 dried up larvae, 4 dried up pupae, 1 dried up flea
,, ,,	22	Beehive	April 64·1 37·3 May 67·9 47·3	—	None emerged	—	—	—	100	Cocoons opened 4 July '12, 21 dried up larvae, 1 "false" cocoon
,, ,,	22	Warm Cupboard	April 59·0 May 62·6	·64 ·70	2 on 20 May 1 ,, 31 ,,	2 1	35 46	—	77	Cocoons opened 4 July '12, 4 dried up pupae, 12 dried up larvae, 3 "false" cocoons
10 May '12	50	Incubator 75 Wet	May 75·6 June 74·9 July 75·0	·86 ·83 ·86	13 ,, 24 ,, 19 ,, 28 ,, 10 ,, 31 ,, 5 ,, 13 June 1 ,, 26 ,, 2 ,, 8 July	13 19 10 5 1 2	14 18 21 34 47 58	21	Nil	—
,, ,,	50	,, 75 Dry	May 74·7 June 75·8	·59 ·54	7 ,, 28 May 8 ,, 31 ,, 5 ,, 3 June 2 ,, 6 ,,	7 8 5 2	18 21 24 27	21	50	1 larva emerged from its cocoon and died; remaining cocoons opened 5 Sept. 23 dead larvae, 1 dead pupa (3 "false" cocoons)

TABLE XXXV.—*Continued.*

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature			Humidity	Date of emergence of fleas	Duration of cocoon stage No. of cocoons	Duration of cocoon stage Days	Aver. days	Mortality per cent.	Remarks
				max.	min.							
10 May '12	50	Incubator 93 Wet	94·1			·76	5 on 20 May	5	10	14	42	Remaining cocoons opened 5 Sept., 15 dead fleas, 5 dead pupae, 1 dead larva (1 "false" cocoon)
							14 ,, 24 ,,	14	14			
							8 ,, 28 ,,	8	18			
							1 ,, 31 ,,	1	21			
13 ,,	50	,, 93 Dry	93·3			·52	3 ,, 24 ,,	3	11	13	84	Remaining cocoons opened 5 Sept., 23 dried up larvae, 10 dried up pupae, 9 dried up fleas (2 "false" cocoons)
							3 ,, 28 ,,	3	15			
,, ,,	50	Cellar	May	54·2	53·2	·93	1 ,, 5 July	1	53	74	86	Remaining cocoons opened 7 Sept. * 1 living flea, 18 dead larvae, 22 dead pupae, 3 dead fleas (2 "false" cocoons)
			June	56·4	55·6	·93	1 ,, 26 ,,	1	74			
			July	60·1	59·3	·93	1 ,, 13 Aug.	1	92			
			Aug.	57·5	56·5	·93	1 ,, 30 ,,	1	109			
			Sept.	56·0	54·3	·92	*1 ,, 7 Sept.	1	116			
,, ,,	50	Lab. Cupboard	May	64·0	56·8	·87	2 ,, 27 June	2	45	72	32	1 larva emerged from cocoon and died; remaining cocoons opened 6 Sept., 8 dried up larvae, 5 dried up pupae, 3 dried up fleas, 2 living fleas, 1 living pupa
			June	64·6	58·3	·81	4 ,, 3 July	4	51			
			July	68·5	62·1	·79	12 ,, 15 ,,	12	63			
			Aug.	63·3	56·3	·84	1 ,, 20 ,,	1	68			
			Sept.	61·5	53·0	·86	2 ,, 27 ,,	2	75			
							1 ,, 2 Aug.	1	81			
							4 ,, 9 ,,	4	88			
							1 ,, 14 ,,	1	93			
							1 ,, 28 ,,	1	107			
							1 ,, 30 ,,	1	109			
							2 ,, 6 Sept.	2	116			
,, ,,	50	Beehive	May	67·9	47·3	—	1 ,, 20 June	1	38	51	72	3 larvae emerged from cocoons and died; remaining cocoons opened 6 Sept., 23 dead larvae, 8 dead pupae, 3 dead fleas (3 "false" cocoons)
			June	67·6	49·9		4 ,, 27 ,,	4	45			
			July	73·4	55·4		3 ,, 4 July	3	52			
							1 ,, 20 ,,	1	68			
							1 ,, 26 ,,	1	74			
16 ,,	50	Warm Cupboard	May	62·6		·70	1 ,, 3 June	1	18	36	26	4 larvae came out of cocoons and died; remaining cocoons opened 5 Sept., 2 dead fleas, 7 dead larvae (4 "false" cocoons)
			June	65·0		·73	9 ,, 8 ,,	9	23			
			July	67·3		·71	6 ,, 12 ,,	6	27			
							7 ,, 21 ,,	7	36			
							1 ,, 27 ,,	1	42			
							4 ,, 2 July	4	47			
							1 ,, 10 ,,	1	55			
							2 ,, 12 ,,	2	57			
							1 ,, 20 ,,	1	65			
							1 ,, 28 ,,	1	73			
24 ,,	50	Incubator 93 Wet	94·0			·78	5 ,, 3 June	5	10	14	32	Remaining cocoons opened 5 Sept., 16 dried up fleas (1 "false" cocoon)
							13 ,, 6 ,,	13	13			
							9 ,, 8 ,,	9	15			
							6 ,, 12 ,,	6	19			

,, ,,	50	,,	93 Dry	May 93·3	·58	None emerged	—	—	—	100	11 larvae emerged from cocoons and died; cocoons opened 5 Sept., 13 dried up fleas, 26 dried up pupae
				June 93·0	·55						
,, ,,	50	,,	75 Wet	May 75·6	·86	7 on 6 June	7	13	22	2	Cocoons opened 5 Sept., 1 dead flea (1 "false" cocoon)
				June 74·9	·83	6 ,, 8 ,,	6	15			
				July 75·0	·86	12 ,, 12 ,,	12	19			
						17 ,, 17 ,,	17	24			
						2 ,, 21 ,,	2	28			
						2 ,, 24 ,,	2	31			
						2 ,, 24 July	2	61			
28 May '12	50	,,	75 Dry	75·8	·57	1 ,, 8 June	1	11	18	32	3 larvae emerged from cocoons and died; remaining cocoons opened 5 Sept., 2 dead fleas, 1 dead pupa, 10 dead larvae (4 "false" cocoons)
						12 ,, 12 ,,	12	15			
						11 ,, 17 ,,	11	20			
						6 ,, 21 ,,	6	24			
				max. min.							
,, ,,	50	Cellar		June 56·4 55·6	·93	3 ,, 15 July	3	48	76	26	Remaining cocoons opened 7 Sept., 10 dead pupae, 13 dead larvae * 4 living fleas (4 "false" cocoons)
				July 60·1 59·3	·93	1 ,, 19 ,,	1	52			
				Aug. 57·5 56·5	·93	1 ,, 26 ,,	1	59			
				Sept. 56·0 54·3	·92	2 ,, 3 Aug.	2	67			
						3 ,, 9 ,,	3	73			
						5 ,, 13 ,,	5	77			
						2 ,, 24 ,,	2	88			
						2 ,, 30 ,,	2	94			
						*4 ,, 7 Sept.	4	102			
,, ,,	50	Lab. Cupboard		June 64·6 58·3	·81	4 ,, 3 July	4	36	62	(?) 18	Cocoons opened 6 Sept., 8 dead larvae, 1 dead pupa † 3 living fleas, remainder of cocoons lost through an accident
				July 68·5 62·1	·79	2 ,, 15 ,,	2	48			
				Aug. 63·3 56·3	·84	3 ,, 20 ,,	3	53			
				Sept. 61·5 53·0	·86	8 ,, 27 ,,	8	60			
						2 ,, 2 Aug.	2	66			
						5 ,, 9 ,,	5	73			
						1 ,, 14 ,,	1	78			
						†3 ,, 6 Sept.	3	101			
,, ,,	50	Beehive		June 67·7 49·9	—	1 ,, 27 June	1	30	54	38	Remaining cocoons opened 6 Sept., 12 dead larvae, 4 dead fleas, 3 dead pupae (3 "false" cocoons)
				July 73·4 55·4		1 ,, 4 July	1	37			
				Aug. 64·9 45·6		4 ,, 15 ,,	4	48			
						14 ,, 20 ,,	14	53			
						5 ,, 26 ,,	5	59			
						1 ,, 2 Aug.	1	66			
						1 ,, 11 ,,	1	75			
						1 ,, 24 ,,	1	88			
,, ,,	50	Warm Cupboard		June 65·0	·73	17 ,, 21 June	17	24	33	20	2 larvae emerged from their cocoons and died; cocoons opened 5 Sept., 6 dead larvae, 2 dead fleas (3 "false" cocoons)
				July 67·3	·71	12 ,, 27 ,,	12	30			
						4 ,, 2 July	4	35			
						1 ,, 12 ,,	1	45			
						2 ,, 20 ,,	2	55			
						1 ,, 26 ,,	1	61			

TABLE XXXV.—*Continued.*

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temperature	Humidity	Dates of emergence of fleas	Duration of cocoon stage		Aver. days	Mortality per cent.	Remarks
						No. of cocoons	Days			
3 June '12	50	Incubator 75 Wet	75·1	·83	1 on 12 June	1	9	17	Nil	Remaining cocoons opened 5 Sept. empty ("false" cocoons)
					23 ,, 17 ,,	23	14			
					9 ,, 21 ,,	9	18			
					13 ,, 24 ,,	13	21			
					1 ,, 28 ,,	1	25			
,, ,,	25	,, 75 Dry	75·8	·59	16 ,, 17 ,,	16	14	16	44	6 larvae emerged from their cocoons and died; cocoons opened 5 Sept., 13 dead larvae, 1 dead pupa, 2 dead fleas
4 ,,	25				10 ,, 21 ,,	9	18			
					2 ,, 25 ,,	1	17			
						2	21			
3 ,,	50	,, 93 Wet	94·2	·78	3 ,, 12 ,,	3	9	14	52	Remaining cocoons opened 4 Sept., 2 dead fleas, 15 dead pupae, 9 dead larvae, 13 "false" cocoons (?)
					3 ,, 17 ,,	3	14			
					4 ,, 21 ,,	4	18			
					1 ,, 24 ,,	1	21			
,, ,,	50	,, 93 Dry	93·0	·54	4 ,, 12 ,,	4	9	11	82	7 larvae emerged from their cocoons and died: remaining cocoons opened 5 Sept., 4 dead fleas, 19 dead pupae, 11 dead larvae, 3 "false" cocoons (?)
					2 ,, 17 ,,	2	14			
6 ,,	42	Cellar	max. min. June 56·4 55·6	·93	4 ,, 26 July	4	50	76	Doubtful	23 cocoons opened 7 Sept., 17 empty, 2 dead fleas, 2 dead pupae, 2 live fleas*; 19 cocoons opened 14 Oct., 13 empty, 2 dead fleas, 2 dead pupae, 1 dead larva, 2 live fleas* ("false" cocoons unrecorded, presumably 15)
			July 60·1 59·3	·93	6 ,, 9 Aug.	6	64			
			Aug. 57·5 56·5	·93	3 ,, 13 ,,	3	68			
			Sept. 56·0 54·3	·92	*2 ,, 7 Sept.	2	93			
					1 ,, 14 Oct.	3	130			
					*2 ,, 14 ,,					
12 July '12	50	Incubator 75 Wet	July 75·0	·86	20 ,, 24 July	20	12	14	14	Cocoons opened 5 Sept., 5 dead larvae, 2 dead pupae (1 "false" cocoon)
			Aug. 74·3	·81	20 ,, 28 ,,	20	16			
					2 ,, 5 Aug.	2	23			
,, ,,	50	,, 75 Dry	July 76·2	·64	8 ,, 24 July	8	12	15	14	Remaining cocoons opened 5 Sept., 3 dead fleas, 3 dead pupae, 1 dead larva (5 "false" cocoons)
			Aug. 75·0	·56	8 ,, 25 ,,	8	13			
			—		14 ,, 28 ,,	14	16			
					7 ,, 31 ,,	7	19			
					1 ,, 3 Aug.	1	22			
,, ,,	50	,, 93 Wet	95·3	·79	5 ,, 24 July	—	—	12	76	Cocoons opened 4 Sept., 13 dried up fleas, 16 dried up pupae, 9 dried up larvae (? 7 "false" cocoons)
,, ,,	50	,, 93 Dry	93·0	·58	16 ,, 20 ,,	16	8	9	60	Cocoons opened 5 Sept., 4 dead fleas, 12 dead pupae, 14 dead larvae (1 "false" cocoon)
					1 ,, 24 ,,	1	12			
					1 ,, 28 ,,	1	16			
					1 ,, 31 ,,	1	19			

TABLE XXXVI. *Cocoons* P. irritans. "*Continuous*"* *series, reared from eggs, each batch maintained during egg-larval and cocoon stage in the same situation.*

Incubator 75 Wet.

Date of commencement of experiment in the egg (or larval) stage	No. of cocoons found	Temp.	Humidity	Approximate duration of cocoon stage No. of cocoons	Days	Average no. of days in cocoon	Mortality in cocoon stage	Food	Remarks
13 July '10	2	75·0	Unrecorded	1	8	10	Nil	Rat faeces	—
				1	13				
19 ,,	3	75·0	·67	1	8	9	33 %	Dead flies	—
				1	11				
11 Aug. '10	4	75·0	·60	4	12	—	Nil	B.S. Rag	—
1 Oct. '10	1	74·4	·73	1	15	—	Nil	B.S. Rag	—
27 Mar. '11	13	75·1	·80	1	9	13	Nil	Rat faeces crushed	3 opened and found to be empty ("false" cocoons)
				1	10				
				1	12				
				3	13				
				1	14				
				2	15				
				1	16				
9 June '11	20	76·0	·84	1	9	15	Nil	B.S. Rag	—
				1	11				
				3	12				
				4	13				
				4	15				
				4	17				
				1	18				
				1	19				
				1	34				
9 ,,	6	76·1	·87	3	11	14	Nil	Flea faeces	One cocoon opened empty ("false" cocoon)
				1	16				
				1	22				

* Experiments in Table XXXVI are for the most part in direct continuity with those dealing with the larval stage given in Table XXI, and up to 15 February 1911 with egg stage experiments given in Table V.

TABLE XXXVI.—*Continued.*

Incubator 85 Wet.

Date of commencement of experiment in the egg (or larval) stage	No. of cocoons found	Temp.	Humidity	Approximate duration of cocoon stage No. of cocoons	Days	Average no. of days in cocoon	Mortality in cocoon stage	Food	Remarks
24 July '10	1	about 85·0	·72	1	23	—	Nil	B.S. Rag	—
6 Aug. '10	1	84·3	·75	1	9	—	Nil	B.S. Rag	—
26 Sept. '10	7	84·4	·72	1	6	7	43 %	Flea faeces	—
				2	7				
				1	11				
29 March '11	15	84·0	·74	1	6	12	11 %	Rat faeces crushed	Remainder (7 cocoons) opened, one found to contain dried up flea, remainder "false" cocoons
				1	8				
				3	12				
				2	14				
				1	21				
6 June '11	18	84·0	·81	1	7	13	Nil	B.S. Rag	2 cocoons opened and found empty ("false" cocoons)
				1	8				
				3	9				
				2	10				
				3	11				
				2	14				
				2	16				
				2	26				
7 "	9	84·2	·80	1	9	13	Nil	Flea faeces	1 cocoon opened and found empty ("false" cocoon)
				2	11				
				4	12				
				1	26				

Laboratory Cupboard.

13 July '10	1	60	·84	1	22	—	Nil	Rat faeces	—
1 Aug. '10	1	60	·84	1	43	—	Nil	Flea faeces	—
11 ,,	6	Approx. only to 8 Nov. 60	·84	1	23	116	Nil	B.S. Rag	—
		max. min.		1	24				
		Nov. 54·0 42·8	·84	1	104				
		Dec. 56·5 47·8	·85	1	114				
		Jan. 53·5 44·0	·84	1	215				
		Feb. 52·8 43·6	·83	1	220				
		Mar. 55·2 45·5	·85						
		Apr. 58·2 48·2	·78						
14 ,,	3	Approx. 60	·84	1	59	—	Nil	—	—
20 ,,	10	Approx. to 8 Nov. 60	·84	1	37	75	Nil	Flea faeces	22 July '11 5 opened and found to be empty (? false cocoons)
		max. min.		1	40				
		Nov. 54·0 42·8	·84	1	55				
		Dec. 56·5 47·8	·85	1	66				
		Jan. 53·5 44·0	·84	1	178				
		Feb. 52·8 43·6	·83	5 opened					
		Mar. 55·2 45·5	·85						
		Apr. 58·2 48·2	·78						
1 Oct. '10	16	(as above)		3	74	83	31 %	B.S. Rag	24 Aug. '11 5 opened and found to contain dried up larvae
				1	77				
				4	81				
				1	86				
				1	87				
				1	113				
				5 opened					
2 ,,	2	—	—	1	143	—	50 %	B.S. Rag	1 cocoon opened 21 Oct. '11 found to contain dried up pupa

TABLE XXXVI.—*Continued.*

Date of commencement of experiment in the egg (or larval) stage	No. of cocoons found	Temp.	Humidity	Approximate duration of cocoon stage		Average no. of days in cocoon	Mortality in cocoon stage	Food	Remarks
				No. of cocoons	Days				
10 ,,	2	(as above to April) May 61·8 54·3 June 66·4 58·2	 ·78 ·79	1	172	—	—	Bran	—
3 June '11	7	72·4 64·1	·73	3 2 2	13 19 20	17	Nil	B.S. Rag	—
12 ,,	13	71·1 63·1	·74	5 1 2 1 4	13 14 18 20 21	17	Nil	Flea faeces	—
						Cellar.			
14 Oct. '10	2	1911 max. min. Feb. 46·4 44·8 Mar. 46·5 45·3 Apr. 48·5 46·6 May 53·9 52·6	 ·92 ·91 ·91 ·92	1 1	38 90	64	Nil	Bran	—
June '11	18	June 58·1 56·7 July 61·6 60·4 Aug. 64·5 63·4 Sept. 60·3 59·5	·93 ·93 ·94 ·93	1 3 3 8 1 2 opened	13 18 19 20 26	19	11 %	B.S. Rag	2 opened 8 Nov. '11 contained 1 dried up larva, 1 dried up flea
12 ,,	17	—	—	4 1 2 2 1 4 1 1	6* 13 18 19 20 26 68 111	27	6 %	Flea faeces	1 cocoon opened 9 Nov. '11 contained living flea; 1 cocoon, opened 14 Dec. 1911, contained a dead flea

* Period may be 3 or 4 days longer owing to lapsus in observation.

TABLE XXXVII. *Cocoons* P. irritans. "*Continuous*" *series, contrasted experiments (compiled from Table XXXVI); larvae from same batch of eggs.*

Date of commencement of experiment in egg stage	Place	No. of cocoons found	Temp.	Humidity	Approximate duration of cocoon stage		Av. no. of days in cocoon	Mortality in cocoon stage	Food
					No. of cocoons	Days			
11 Aug. '10	Incubator 75 Wet	4	75·0	·60	4	12	12	Nil	B.S. Rag
			Approximate only to 8 Nov.						
11 ,,	Laboratory Cupboard	6	60	·84	1	23	116	Nil	B.S. Rag
			max. min.		1	24			
			Nov. 54·0 42·8	·84	1	104			
			Dec. 56·5 47·8	·85	1	114			
			Jan. 53·5 44·0	·84	1	215			
			Feb. 52·8 43·6	·83	1	220			
			Mar. 55·2 45·5	·85					
			Apr. 58·2 48·2	·78					

TABLE XXXVIII. *Cocoons* P. irritans. *Larvae all reared and cocoons spun in Incubator* 75 *Wet; cocoons then removed to various situations.*

(*a*) Jan.—April 1911. Temperature of Incubator 75 Wet, 74·4, Humidity ·77 for Jan., ·70 for March and April.

Date on which cocoons were placed under test conditions	No.	Place		Temp. max.	Temp. min.	Humidity	Dates of emergence of fleas		Approximate duration of cocoon stage No. of cocoons	Days	Aver.	Mortality	Remarks
3 Jan. '11	16	Beehive	Jan.	43·9	32·0	—	1	on 21 March	1	77	—	93 %	Remainder opened 17 Aug. '11 contained 1 dried up flea, 7 dried up pupae, 5 dried up larvae (2 "false" cocoons)
			Feb.	43·8	30·7	—							
			Mar.	52·5	33·3	—							
2 March	2	Incubator 85 Wet		83·9		·71	3	11 ,,	2	7	8	20	1 cocoon opened 19 Sept. '11 contained dried up larva
4 ,,	3						1	12 ,,	1	8			
									1	9			
12 ,,	4	,, 85 Dry		84·0		·58	1	22 ,,	1	10	12	50	2 cocoons opened 19 Sept., 1 contained dried up flea, 1 contained dried up larva
							1	27 ,,	1	15			
20 ,,	2	Lab. Cupboard	Mar.	52·2	45·5	·85	1	4 May	2	43	58	Nil	Remaining cocoons "false"
19 April	5		Apr.	58·2	48·2	·78	1	27 ,,	1	45			
			May	61·8	54·3	·78	2	2 June	1	52			
			June	66·4	58·2	·79	1	10 ,,	1	68			
			July	71·5	62·7	·75	1	27 July	1	99			
27 March	3	Cellar	Mar.	46·5	45·3	·91	1	26 June	1	91	116	33	Remaining cocoon opened contained dead flea
			Apr.	48·5	46·6	·91	1	16 Aug.	1	142			
			May	53·9	52·6	·92							
			June	58·1	56·7	·93							
			July	61·6	60·4	·93							
			Aug.	64·5	63·4	·94							
15 April	8	Incubator 75 Dry		75·2		·50	1	23 April	1	8	14	38	Remaining cocoons opened contained dried up larvae
							1	27 ,,	1	12			
							1	28 ,,	1	13			
							1	30 ,,	1	15			
							1	9 May	1	24			
19 ,,	5	Warm Cupboard	Apr.	63·0		·57	1	29 ,,	1	40	44	Nil	
			May	62·9		·60	1	30 ,,	1	41			
			June	66·6		·65	1	2 June	1	43			
							1	7 ,,	1	48			
							1	9 ,,	1	50			

(*b*) Special experiment with cocoons taken from the same batch; larvae reared and cocoons spun in Incubator 75 Wet. (Temp. April—May 1911, 75° F., Humidity ·82).

10 May '11	10	Incubator 75 Dry		75·0		·53	1 on	21 May	11	14	Nil	5 cocoons opened 16 May contained 4 living pupae and 1 larval skin
							1	22 ,,	12			
							2	24 ,,	14			
							1	26 ,,	16			
							1	29 ,,	19			
11—12 May	12	,, 85 Dry		83·9		·60	3	21 ,,	9	10	8	1 cocoon opened 23 Oct. contained dried up larva
							5	22 ,,	10			
							1	24 ,,	12			
							2	26 ,,	14			
13—15 ,,	11	,, 85 Wet		84·0		·76	5	22 ,,	7	9	Nil	1 cocoon opened 2 Oct. empty ("false cocoon")
							3	25 ,,	10			
							2	26 ,,	11			
20—22 ,,	18	,, 75 Wet		76·0		·86	6	1 June	10	18	Nil	Remaining cocoons opened 2 Oct. empty ("false" cocoons)
							2	2 ,,	11			
							4	6 ,,	15			
							1	30 ,,	39			
							1	2 Aug.	72			
16—19 ,,	17	Lab. Cupboard	May	65·0	56·5	·78	8	10 June	22	25	20	5 cocoons opened 21 Oct., 1 contained dried up larva, 2 contained dried up pupae, 2 empty "false" cocoons
			June	66·4	58·2	·79	2	18 ,,	30			
							1	20 ,,	32			
							1	27 ,,	39			
16—19 ,,	16	Cellar	May	53·9	52·6	·92	1	5 July	47	139	Nil	Remaining cocoons opened 21 June '12, 2 "false" cocoons
			June	58·1	56·7	·93	1	27 ,,	69			
			July	61·4	60·4	·93	1	9 Aug.	82			
			Aug.	64·5	63·4	·94	2	16 ,,	89			
			Sept.	60·6	59·5	·93	1	21 ,,	94			
							1	5 Sept.	109			
							1	16 Oct.	150			
							1	20 Nov.	170			
							1	22 Dec.	202			
							3	25 ,,	205			
							1	25 Jan.	236			
20—22 ,,	12	Beehive	May	76·0	48·0	—	2	6 June	15	26	16	2 cocoons opened 25 Oct. contained 1 dried up flea, 1 dried up larva
			June	73·0	56·5	—	5	10 ,,	19			
			July	74·1	55·4	—	1	20 ,,	29			
							1	14 July	53			
							1	18 ,,	57			

TABLE XXXVIII.—*Continued.*

(*c*) Special experiment with cocoons taken from the same batch; larvae reared and cocoons spun in Incubator 75 Wet. (Temp. May—June 1911, 75° F., Humidity ·84).

Date on which the cocoons were placed under test conditions	No. of cocoons	Place		Temp. max.	Temp. min.	Humidity	Dates of emergence of fleas		Approximate duration of cocoon stage No. of cocoons	Days	Aver.	Mortality	Remarks
23—26 May '11	52	Cellar	May	53·9	52·6	·92	1 on	20 June	1	25	89	Apparently Nil	Remaining cocoons empty, i.e. false
			June	58·1	56·7	·93	3	26 ,,	3	31			
			July	61·6	60·4	·93	2	5 July	2	40			
			Aug.	64·5	63·4	·94	3	12 ,,	3	47			
			Sept.	60·6	59·5	·93	5	27 ,,	5	62			
			Oct.	56·3	54·8	·92	4	1 Aug.	4	67			
			Nov.	50·7	48·9	·91	3	9 ,,	3	75			
			Dec.	48·7	47·4	·92	6	11 ,,	6	77			
							1	16 ,,	1	82			
							1	21 ,,	1	87			
							1	28 ,,	1	94			
							1	5 Sept.	1	102			
							2	1 Nov.	2	159			
							3	27 ,,	3	185			
							2	20 Dec.	2	208			
							1	29 ,,	1	217			
27—30 ,,	41	Lab. Cupboard	June	66·4	58·2	·79	8	17 June	8	18	53	15	Cocoons opened 2 July '12, 2 contained dried up fleas, 1 contained dried up pupa, 3 contained dried up larvae. 3 false cocoons
			July	71·5	62·7	·75	2	20 ,,	2	21			
			Aug.	72·0	64·1	·74	1	26 ,,	1	27			
			Sept.	65·7	55·7	·77	1	5 July	1	36			
			Oct.	59·0	50·9	·84	2	12 ,,	2	43			
							3	21 ,,	3	52			
							1	27 ,,	1	58			
							2	2 Aug.	2	64			
							2	9 ,,	2	71			
							5	16 ,,	5	78			
							2	30 ,,	2	92			
							1	6 Sept.	1	98			
							2	9 ,,	2	101			
31 May—2 June	46	Beehive	June	73·0	56·5	—	1	6 June	1	4	44	32	6 larvae emerged from cocoons and died. Cocoons opened contained 2 dead fleas, 1 dead pupa, 6 dead larvae. Remaining cocoons empty (false)
			July	80·3	58·6	—	1	14 ,,	1	12			
			Aug.	80·2	57·6	—	3	20 ,,	3	18			
							1	24 ,,	1	22			
							1	14 July	1	42			
							2	18 ,,	2	46			
							4	24 ,,	4	52			
							6	29 ,,	6	57			
							2	2 Aug.	2	61			
							1	12 ,,	1	67			

3—7 June	70	Warm Cupboard	June 66·6	·65	1	12 June	1	5	23	30	Remaining cocoons opened 13 Dec. contained 2 dried up fleas, 19 dried up larvae
			July 71·3	·65	10	19 ,,	10	12			
			Aug. 75·0	·66	3	20 ,,	3	13			
					4	21 ,,	4	14			
					4	23 ,,	4	16			
					6	24 ,,	6	17			
					3	26 ,,	3	19			
					1	27 ,,	1	20			
					1	29 ,,	1	22			
					1	3 July	1	26			
					1	4 ,,	1	27			
					1	5 ,,	1	28			
					2	10 ,,	2	33			
					2	13 ,,	2	36			
					2	17 ,,	2	40			
					4	19 ,,	4	42			
					1	22 ,,	1	45			
					1	3 Aug.	1	57			
					1	17 ,,	1	71			
8—9 ,,	25	Incubator 75 Dry	75·3	·55	2	19 June	2	10	14	48	Remaining cocoons opened 13 Dec. contained 3 dried up fleas, 9 dried up larvae
					2	20 ,,	2	11			
					4	21 ,,	4	12			
					1	23 ,,	1	14			
					3	24 ,,	3	15			
					1	17 July	1	38			
10—13 ,,	20	,, 85 Dry	84·1	·64	1	16 June	1	3	15	45	9 cocoons opened 23 Oct. contained 3 dried up fleas, 1 dried up pupa, 5 dried up larvae
					7	26 ,,	7	13			
					1	17 July	1	34			
					2	24 ,,	2	41			
14—16 ,,	26	,, 85 Wet	84·6	·82	1	19 June	1	3	12·7	Nil	1 false cocoon
					6	23 ,,	6	7			
					6	24 ,,	6	8			
					7	26 ,,	7	10			
					2	29 ,,	2	13			
					1	11 July	1	25			
					1	13 ,,	1	27			
					1	1 Sept.	1	77			
25—27 ,,	33	,, 75 Wet	75·5	·82	4	4 July	4	7	20·6	Nil	Cocoons all opened 4 July '12 and 5 found to be empty ("false" cocoons)
					7	7 ,,	7	10			
					7	10 ,,	7	13			
					2	11 ,,	2	14			
					1	17 ,,	1	20			
					2	24 ,,	2	27			
					1	2 Aug.	1	36			
					1	15 ,,	1	49			
					1	23 ,,	1	57			
					1	4 Sept.	1	69			
					1	9 ,,	1	74			

TABLE XXXVIII.—*Continued.*

(*d*) Special experiment with cocoons taken from the same batch; larvae reared and cocoons spun in Incubator 75 Wet. (Temp. August 1911, 75·7° F., Humidity ·83).

Date on which the cocoons were placed under test conditions	No. of cocoons	Place		Temp. max.	Temp. min.	Humidity	Dates of emergence of fleas	Approximate duration of cocoon stage No. of cocoons	Days	Aver.	Mortality	Remarks
1 Aug. '11	36	Cellar	Aug.	64·5	63·4	·94	4 on 21 Aug.	4	20	110	Nil	4 cocoons missing, probably they were slightly spun and deserted by the larvae and subsequently fell to pieces
			Sept.	60·3	59·5	·93	3 28 ,,	3	27			
			Oct.	56·3	54·8	·92	2 11 Sept.	2	41			
			Nov.	50·7	48·9	·91	1 16 Oct.	1	76			
			Dec.	48·7	47·4	·92	5 1 Nov.	5	92			
			Jan.	47·2	45·9	·92	1 9 ,,	1	100			
			Feb.	45·8	44·6	·92	1 20 ,,	1	111			
			Mar.	49·1	48·1	·93	1 7 Dec.	1	128			
			Apr.	50·3	49·1	·93	4 20 ,,	4	141			
							1 22 ,,	1	143			
							1 4 Jan.	1	156			
							2 25 ,,	2	177			
							1 31 ,,	1	183			
							1 6 Feb.	1	187			
							2 13 ,,	2	196			
							1 26 ,,	1	209			
							1 27 March	1	239			
5 ,,	39	Lab. Cupboard	Aug.	72·0	64·1	·74	8 16 Aug.	8	11	40	10	Remaining cocoons opened 3 July '12 contained 1 dried up flea, 3 dried up larvae, 2 false cocoons
			Sept.	65·7	55·7	·77	18 30 ,,	18	25			
			Oct.	59·0	50·9	·84	1 9 Sept.	1	34			
			Nov.	54·9	46·1	·85	1 13 Oct.	1	69			
			Dec.	53·9	46·2	·87	1 20 ,,	1	76			
			Jan.	52·5	44·9	·89	1 7 Dec.	1	124			
			Feb.	54·4	45·3	·86	1 22 ,,	1	139			
							1 4 Jan.	1	152			
							1 17 Feb.	1	196			
8 ,,	33	Beehive	Aug.	80·2	57·6	—	7 17 Aug.	7	9	16	3	Remainder of cocoons opened 23 June '12 contained 1 dead larva, 8 false cocoons
			Sept.	75·3	48·0	—	12 22 ,,	12	14			
							1 26 ,,	1	18			
							1 28 ,,	1	20			
							1 9 Sept.	1	32			
							1 16 ,,	1	39			
							1 22 ,,	1	45			

11 ,,	18	Warm Cupboard	Aug. 75·0	·66	8	22 Aug.	8	11	19	17	Remainder of cocoons opened 13 Dec. contained 3 dried up larvae
			Sept. 66·3	·66	4	25 ,,	4	14			
			Oct. 67·4	·59	1	8 Sept.	1	28			
					1	30 ,,	1	50			
					1	23 Oct.	1	73			
14 ,,	26	Incubator 75 Dry	74·9	·59	14	25 Aug.	14	11	14	19	Remaining cocoons opened 13 Dec. contained 5 dried up larvae
					2	28 ,,	2	14			
					5	4 Sept.	5	21			
18 ,,	53	,, 85 Dry	85·7	·59	6	25 Aug.	6	7	14	23	Remaining cocoons opened 16 Mar. '12 contained 2 dead fleas, 10 dead larvae
					13	28 ,,	13	10			
					19	4 Sept.	19	17			
					2	8 ,,	2	21			
					1	25 ,,	1	38			
23 ,,	42*	,, 85 Dry	84·2	·59	3	28 Aug.	3	5	14	26	Remaining cocoons opened 16 Mar. '12 coutained 2 dead fleas, 9 dead larvae
					15	4 Sept.	15	12			
					8	8 ,,	8	16			
					3	9 ,,	3	17			
					1	14 ,,	1	22			
					1	19 ,,	1	27			
23 ,,	42*	Cellar	Aug. 64·5 63·4	·94	4	11 ,,	4	19	89	2	Remaining cocoons opened 21 June '12 contained 1 dead flea, 1 "false" cocoon
			Sept. 60·3 59·5	·93	3	19 ,,	3	27			
			Oct. 56·3 54·8	·92	2	20 ,,	2	28			
			Nov. 50·7 48·9	·91	3	26 ,,	3	34			
			Dec. 48·7 47·4	·92	3	2 Oct.	3	40			
			Jan. 47·2 45·9	·92	2	16 ,,	2	54			
			Feb. 45·8 44·6	·92	2	1 Nov.	2	70			
			Mar. 49·1 48·1	·93	2	9 ,,	2	78			
			Apr. 50·3 49·1	·93	1	20 ,,	1	89			
					1	27 ,,	1	96			
					1	11 Dec.	1	110			
					5	20 ,,	5	119			
					1	22 ,,	1	121			
					1	25 ,,	1	124			
					2	10 Jan.	2	140			
					1	31 ,,	1	161			
					3	19 Feb.	3	180			
					2	2 March	2	192			
					1	10 April	1	231			

* Refer to the same batch of cocoons; the batch was divided, half being placed in Incubator 85 Dry, the remainder being put into cellar for comparison.

TABLE XXXVIII.—*Continued.*

(*e*) Special experiment with cocoons taken from the same batch; larvae reared and cocoons spun in Incubator 75 Wet. (Temp. Nov.—Dec. 1911, 75° F., Humidity ·70.)

Date on which the cocoons were placed under test conditions	No. of cocoons	Place	Temp.	Humidity	Dates of emergence of fleas		Approximate duration of cocoon stage No. of cocoons	Days	Aver.	Mortality	Remarks
6 Nov. '11	16	Incubator 93 Dry	92·9	·56	2	on 13 Nov.	2	7	12	69	Cocoons opened 16 March '12 contained 7 dead fleas, remainder 4 dead larvae
					2	16 ,,	2	10			
					1	1 Dec.	1	25			
16 ,,	22	,, 85/93 Wet	84·2	·72*	2	29 Nov.	2	13	—	Doubtful	Cocoons opened 11 May '12 contained 6 dead pupae, 4 dead larvae, 10 unaccounted for, presumably false cocoons
			93·0	·66							
17 ,,	16	,, 75 Dry	74·5	·56	2	5 Dec.	2	18	—	87	Cocoons opened 13 Dec. contained 14 dried up larvae
21 ,,	19	,, 75 Wet	Nov. 75·0	·69	2	1 ,,	2	10	28	21	Cocoons opened 4 July '12 contained 2 dried up fleas, 2 dried up larvae, 2 false cocoons
			Dec. 75·8	·65	7	5 ,,	7	14			
			Jan. 75·5	·71	1	16 ,,	1	25			
			Feb. 75·0	·76	1	24 ,,	1	33			
			Mar. 75·1	·79	1	1 Jan.	1	41			
			Apr. 75·8	·79	1	16 May	1	146			
			May 75·6	·86							
21 ,,	19	Warm Cupboard	Nov. 63·0	·58	2	5 Dec.	2	14	34	10	Cocoons opened 4 July '12 contained 2 dried up larvae, 1 false cocoon
			Dec. 62·3	·62	1	7 ,,	1	16			
			Jan. 59·7	·60	2	11 ,,	2	20			
			Feb. 59·5	·63	2	13 ,,	2	22			
					1	18 ,,	1	27			
					1	22 ,,	1	31			
					1	26 ,,	1	35			
					1	4 Jan.	1	44			
					2	8 ,,	2	48			
					1	25 ,,	1	65			
					1	12 Feb.	1	83			
23 ,,	17	Beehive	max. min. Nov. 23 to 30 42·0 32·7	—		No emergence			—	100	Cocoons opened 23 June '12; many of the cocoons very frail and in fragments, apparently there had been 5 false cocoons. There were 12 dead larvae
			Dec. 46·8 35·0 Thermometer fell to 23° for three nights, Dec. 6—8	—							

* Up to 29 Nov. ·72, subsequently ·66.

28 ,,	24	Lab. Cupboard	Nov.	54·9	46·1	·85	1	29 Dec.	1	31	95	12	Cocoons opened 13 June '12 contained 1 dried up flea, 2 dried up larvae
			Dec.	53·9	46·2	·87	1	4 Jan.	1	37			
			Jan.	52·5	44·9	·89	1	8 ,,	1	41			
			Feb.	54·4	45·3	·86	3	25 ,,	3	58			
			Mar.	56·0	47·8	·76	2	17 Feb.	2	81			
			Apr.	60·6	50·4	·83	1	20 ,,	1	84			
							1	29 ,,	1	93			
							1	5 March	1	98			
							1	11 ,,	1	103			
							1	25 ,,	1	118			
							3	28 ,,	3	121			
							2	1 April	2	125			
							1	20 ,,	1	144			
							1	24 ,,	1	148			
							1	30 ,,	1	154			
7 Dec.	31	Cellar	Dec.	48·7	47·4	·92	1	31 Jan.	1	55	115	32	Cocoons opened 22 June '12 contained 10 dead fleas, 3 false cocoons
			Jan.	47·2	45·9	·92	2	6 Feb.	2	61			
			Feb.	45·8	44·6	·92	2	13 ,,	2	68			
			Mar.	49·1	48·1	·93	2	7 March	2	91			
			Apr.	50·3	49·1	·93	1	13 ,,	1	99			
			May	54·2	53·2	·93	1	16 April	1	131			
			June	56·4	55·6	·93	1	26 ,,	1	141			
							1	3 May	1	148			
							1	9 ,,	1	154			
							2	16 ,,	2	161			
							1	21 ,,	1	166			
							2	25 ,,	2	170			
							1	4 June	1	180			

(*f*) Special experiment with cocoons taken from the same batch; larvae reared and cocoons spun in Incubator 75 Wet. Feb.—March, 1912. (Temperature 75° F., Humidity ·76.)

26 Feb. '12	21	Incubator 93 Wet		92·6		·66	5	5 March	5	8	10	33	Cocoons opened 2 July contained 6 dried up fleas, 1 dried up larva, 2 false cocoons. 1 unaccounted for
							4	9 ,,	4	12			
							2	12 ,,	2	15			
28 ,,	11	,, 75 Wet		75·6		·78	10	12 ,,	10	13	13	Nil	—
							1	14 ,,	1	15			
1 Mar. '12	10	,, 75 Dry		73·2		·56	2	14 ,,	2	13	16	20	Cocoons opened 2 July contained 2 dried up larvae, 1 false cocoon
							4	18 ,,	4	17			
							1	22 ,,	1	21			

Table XXXVIII.—*Continued.*

(*g*) Emergence of adults from stock of cocoons kept in Laboratory Cupboard, larvae reared and cocoons spun in Laboratory Cupboard.

Dates when cocoons were found		Temperature		Humidity	Dates of emergence	Average	Approx. no. of days in cocoon
		max.	min.				
1 on 15 Sept. '10	Sept. '10	about 60		·84	1 on 27 Jan. '11	143 days	1 in 134
3 21 ,,	Oct.	,,		·84	4 27 Feb. '11		* 1 155
2 25 ,,	Nov.	54·0	42·8	·84	2 1 March '11		1 157
Remainder during October	Dec.	56·5	47·8	·85	1 2 ,,		3 159
	Jan. '11	55·5	44·0	·84	2 3 ,,		1 121
	Feb.	52·8	43·6	·83	2 4 ,,		1 122
	March	55·2	45·5	·85	1 9 ,,		1 123
	April	58·2	48·2	·78	2 20 ,,		2 124
					1 23 ,,		† 1 129
					1 1 April '11		2 140
					1 18 ,,		1 143
					1 21 ,,		1 151
							1 169
							1 172

* These were assumed to have emerged from the Sept. cocoons.

† All dates calculated from 31 Oct. '11. One cocoon was kept apart so that its date of emergence can be definitely fixed at 169 days.

TABLE XXXIX. Cocoons P. irritans. *Larvae reared in Incubator 75 Wet (Temperature 75° F., Humidity ·78) these allowed to spin under one set of conditions and transferred to contrasting conditions for the cocoon stage.*

Date on which larvae were removed from Incubator 75 Wet	No. of larvae	Place in which larvae formed their cocoons and date when found and transferred	Temperature max.	Temperature min.	Humidity	Place to which cocoons were transferred and date of emergence of fleas	Temperature	Humidity	Approximate duration of cocoon stage No. of cocoons	Days	Aver.	Mortality	Remarks
27 April '11	10	Beehive 1 18 May 1 26 ,, Remainder of larvae dead	69·1	43·7	—	Incubator 85 Wet 1 29 May 1 6 June	84·7	·80	2	11	—	Nil	—
27 April	10	Incubator 85 Wet 2 2 May 3 4 ,, 3 5 ,, Remainder of larvae dead	83·5		·75	Beehive 2 30 May 2 16 June 1 20 ,,	max. min. May 71·8 45·2 June 73·0 56·5	— —	2 2 1	28 43 47	23	37 %	3 cocoons opened 30 Sept. contained 1 dried up flea, 2 dried up larvae
2 May	10	Lab. Cupboard 1 9 May 2 13 ,, 1 23 ,, 1 27 ,, 1 1 June 1 larva emerged from cocoon and failed to spin again Remainder of larvae dead	61·8	54·3	·78	Incubator 75 Dry 2 23 May 1 7 June 1 13 ,,	75·3	·53	1 1 1 1	10 14 21 25	17	20 %	Remaining cocoons opened 23 Oct. contained dried up larvae
27 April	10	Cellar 1 9 May 2 18 ,, 2 27 ,, 1 3 June 1 8 ,, 2 larvae emerged from cocoons and failed to spin again Remainder of larvae dead	54·8	53·4	·92	Incubator 85 Dry 1 20 June 1 2 Aug.	84·1	·61	1 1	41 76	58	60 %	Remaining cocoons opened 2 Oct. contained dried up larvae
2 May	10	Incubator 85 Dry 7 8 May 1 11 ,, Remainder dead	84·3		·59	Cellar 2 3 June 2 20 ,, 1 12 July 1 1 Aug.	May 53·9 52·6 June 58·1 56·7 July 61·6 60·4	·92 ·93 ·93	2 2 1 1	26 43 65 85	48	Nil	Remaining cocoons opened and found empty (false cocoons)
2 May	16	Incubator 75 Wet 4 5 May 9 8 ,, 3 10 ,, 1 12 ,,	74·4		·83	Warm Cupboard 1 19 May 1 21 ,, 1 23 ,, 1 24 ,, 1 26 ,, 2 29 ,, 4 31 ,, 1 1 June 2 6 ,, 1 8 ,,	May 62·9 June 66·6	·60 ·65	1 1 2 1 2 4 1 1 2	14 16 18 19 21 23 24 27 29	22	12 %	1 larva came out of cocoon and died, 1 cocoon opeued 30 Sept. contained dried up larva

TABLE XL. *Cocoon stage* Ct. canis.

(*a*) Larvae taken from dog's bed placed in large glass tubes and allowed to spin and to pass the cocoon stage in the same place (1) in Incubator 75 Wet and (2) in the Cellar.

Date on which larvae were put into tubes	No. of cocoons	Place to which cocoons were transferred	Temperature	Humidity	Date of emergence of fleas	Mortality	Remarks
26 April '11	17 cocoons found	Incubator 75 Wet	April 75·0 May 74·9 June 75·8	·78 ·85 ·86	1 on 8 May '11 3 10 ,, 1 23 ,, 1 27 ,, 3 1 June '11 14 6 ,, 1 8 ,,	*	—
,,	28 cocoons found	Cellar	April 48·5 46·6 May 53·9 52·6 June 58·1 56·7 July 61·6 60·4 Aug. 64·5 63·4	·91 ·92 ·93 ·93 ·94	2 5 July '11 7 12 ,, 4 3 Aug. '11 1 9 ,,	—	—

(*b*) Larvae taken from dog's bed and allowed to spin in Laboratory Cupboard, November 1910; cocoons then removed to various situations.

Date on which cocoons were placed under test conditions							
17 Nov. '10†	7	Incubator 85 Wet	83·9	·71	1 23 Nov. '10 5 25 ,,	Nil	1 cocoon opened and found to be empty ("false" cocoon)
,, †	7	,, 75 Wet	74·2	·73	1 25 ,, 3 30 ,,	14 %	2 cocoons opened found to be empty (1 dead flea, 1 "false" cocoon)
,, †	6	Warm Cupboard	max. min. 67·5 61·0	·54	2 4 Dec. '10 1 7 ,, 2 8 ,,	16 %	1 cocoon opened found to contain dead flea
,, †	7	Cellar	48·6 47·1	·92	1 13 Feb. '10 1 18 ,,	71 %	5 cocoons opened contained dead fleas

* NOTE. No accurate figures of mortality can be given.

† There is some doubt as to the correct date of spinning, the date given is the date of transfer only, the number of days in cocoon is not definite.

(c) Larvae taken from dog's bed and allowed to spin in Incubator 75 Wet (Temperature 76° F., Humidity ·84); cocoons then removed to various situations.

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred	Temperature			Humidity	Date of emergence of fleas		Approximate duration of cocoon stage No. of cocoons	Days	Average	Remarks
				max.	min.							
31 July '11	about 100	Incubator 75 Wet	74·9			·77	85 on	15 Aug. '11	85	15	16	Remaining cocoons opened 16 Dec. '11 contained dried up larvae
							7	17 ,,	7	17		
							1	18 ,,	1	18		
							2	12 Oct. '11	2	72		
,,	,, 100	,, 75 Dry	75·7			·59	78	14 Aug. '11	78	14	15	Remaining cocoons opened 13 Dec. '11 contained dried up fleas
							1	25 ,,	1	25		
							1	28 ,,	1	28		
							1	4 Sept. '11	1	35		
,,	,, 100	,, 85 Wet	84·8			·79	77	14 Aug. '11	77	14	15	Remaining cocoons opened 16 Dec. '11 contained dried up fleas
							1	21 ,,	1	21		
							1	28 ,,	1	28		
							1	12 Sept. '11	1	43		
							1	19 ,,	1	50		
,,	,, 100	,, 85 Dry	84·0			·61	80	14 Aug. '11	80	14	15	Remaining cocoons opened 16 Dec. '11 contained dried up fleas
							3	25 ,,	3	25		
							1	19 Sept. '11	1	50		
,,	,, 100	Cellar	Aug.	64·5	63·4	·94	12	16 Aug. '11	12	16	130	Remaining cocoons opened 7 Sept. '12 contained 2 dead fleas
			Sept.	60·6	59·5	·93	21	28 ,,	21	28		
			Oct.	56·3	54·8	·92	9	11 Sept. '11	9	42		
			Nov.	50·7	48·9	·91	3	19 ,,	3	50		
			Dec.	48·7	47·4	·92	1	16 Oct. '11	1	80		
			1912				2	9 Nov. '11	2	101		
			Jan.	47·2	45·9	·92	6	20 Dec. '11	6	142		
			Feb.	45·8	44·6	·92	3	22 ,,	3	144		
			Mar.	49·1	48·1	·93	2	25 ,,	2	147		
			April	50·3	49·1	·93	1	29 ,,	1	151		
			May	54·2	53·2	·93	4	4 Jan. '12	4	157		
			June	56·4	55·6	·93	11	10 ,,	11	163		
			July	60·1	59·3	·93	8	6 Feb. '12	8	190		
							1	19 ,,	1	203		
							3	26 ,,	3	210		
							6	21 Mar. '12	6	234		
							5	27 ,,	5	240		
							3	4 April '12	3	248		
							2	10 ,,	2	258		
							4	26 ,,	4	270		
							2	9 May '12	2	283		
							2	25 ,,	2	299		
							1	19 July '12	1	354		

TABLE XL.—*Continued.*

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred		Temperature max.	Temperature min.	Humidity	Date of emergence of fleas	Approximate duration of cocoon stage No. of cocoons	Days	Average	Remarks
31 July '11	about 100	Lab. Cupboard	Aug.	72·0	64·1	·74	80 on 16 Aug. '11	80	16	67	Cocoons opened, no dead found
			Sept.	65·7	55·7	·77	5 30 ,,	5	30		
			Oct.	59·0	50·9	·84	2 6 Sept. '11	2	37		
			Nov.	54·9	46·1	·85	1 19 Dec. '11	1	141		
			Dec.	53·9	46·2	·87	1 22 ,,	1	144		
			1912				1 25 ,,	1	147		
			Jan.	52·5	44·9	·89	2 10 Feb. '12	2	194		
			Feb.	54·4	45·3	·86	1 17 ,,	1	201		
			Mar.	56·0	47·8	·76	3 20 ,,	3	204		
			April	60·6	50·4	·83	1 23 ,,	1	207		
							3 5 Mar. '12	3	218		
							3 11 ,,	3	224		
							1 21 ,,	1	234		
							1 25 ,,	1	238		
							1 28 ,,	1	241		
							2 1 April '12	2	245		
							3 14 ,,	3	258		
							3 24 ,,	3	268		
							1 30 ,,	1	274		
,,	,, 100	Beehive		80·2	57·6	—	20 14 Aug. '11	20	14	18	Cocoons opened contained 7 dried up fleas
							48 18 ,,	48	18		
							26 22 ,,	26	22		
							1 26 ,,	1	26		
,,	,, 100	Warm Cupboard	Aug.	Dry 75·0		·66	80 14 ,,	80	14	16	Remaining cocoons opened 13 Dec. '11 contained dried up fleas
			Sept.	66·3		·66	5 17 ,,	5	17		
			Oct.	67·4		·59	7 22 ,,	7	22		
							1 23 Sept. '11	1	54		
							1 25 ,,	1	56		
							1 12 Oct. '11	1	73		

NOTE. No accurate figures of mortality can be given.

(*d*) Larvae taken from a dog's bed and allowed to spin in Incubator 75 Wet; cocoons then removed to various situations.

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred	Temperature	Humidity	Date of emergence of fleas	Number of days in cocoon	Average	Remarks
8 July '12	50 approx.	Incubator 93 Wet	94·8	·82	1 on 13 July '12	5	9	Cocoons opened 4 Sept. contained 4 dead fleas, 22 dead pupae, 11 dead larvae
					3 19 ,,	11		
12 ,,	50 ,,	,, 93 Dry	93·0	·57	21 19 ,,	7	8	Cocoons opened 4 Sept. contained 10 dead fleas, 2 dead pupae, 6 dead larvae
					6 24 ,,	12		
					2 28 ,,	16		
12 ,,	50 ,,	,, 75 Wet	75·0	·86	4 18 ,,	6	12	Cocoons opened 5 Sept. all empty: probably no mortality
					38 24 ,,	12		
					2 28 ,,	16		
					1 4 Aug. '12	23		
12 ,,	50 ,,	,, 75 Dry	76·2	·64	2 19 July '12	7	12	Cocoons opened 5 Sept. contained 1 dead larva, remainder empty
					39 24 ,,	12		
					2 28 ,,	16		
					1 1 Aug. '12	20		
12 ,,	50 ,,	* Cellar	July max. 60·1 min. 59·3	·93	†10 7 Sept. '12	57	129	1 dead flea found in cocoon, remaining cocoons empty
			Aug. 57·5 56·5	·93	1 28 ,,	78		
			Sept. 56·0 54·3	·92	†2 11 Oct. '12	91		
					3 14 ,,	94		
					†12 14 ,,	94		
					1 17 ,,	97		
					1 31 ,,	111		
					1 13 Nov. '12	124		
					1 21 ,,	132		
					1 23 ,,	134		
					1 19 Dec. '12	160		
					1 21 ,,	162		
					1 17 Feb. '13	220		
					1 25 Mar. '13	256		
					7 emerged between May and July	say 292		

* No record of temperature or humidity kept subsequently to Sept. 1912.

† Taken out of cocoons.

NOTE. No accurate figures of mortality can be given.

TABLE XL.—*Continued.*

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred		Temperature max.	Temperature min.	Humidity		Date of emergence of fleas	Number of days in cocoon	Average	Remarks
12 July '12	50 ,,	*Lab. Cupboard	July	68·5	62·1	·79	2	27 July '12	15	At least 133	Remaining cocoons empty
			Aug.	63·3	56·3	·84	8	2 Aug. '12	21		
			Sept.	61·5	53·0	·86	4	9 ,,	28		
							2	30 ,,	49		
							†2	6 Sept. '12	56		
							1	30 ,,	65		
							1	20 Nov. '12	116		
							3	21 Dec. '12	147		
							4	4 Feb. '13	192		
							1	9 ,,	197		
							1	5 Mar. '13	221		
							3	8 ,,	224		
							1	25 ,,	241		
							10	emerged subsequently	say 250		
15 ,,	50 ,,	Warm Cupboard	July	67·3		·71	1	26 July '12	11	29	Cocoons opened 5 Sept. contained 9 live fleas, 5 dead fleas, 1 dead larva; 2 dead fleas from 1 cocoon. Several cocoons spun back to back, in one of these double cocoons one compartment contained a dead flea and the other a live one
			Aug.	64·5		·71	5	30 ,,	15		
							6	3 Aug. '12	19		
							13	7 ,,	23		
							4	9 ,,	25		
							2	12 ,,	28		
							1	25 ,,	41		
							3	30 ,,	46		
							9	5 Sept. '12	52		
15 ,,	50 ,,	*Beehive	July	73·4	55·4		2	9 Aug. '12	25	129	Some cocoons opened 6 Sept. contained 2 living fleas Remaining cocoons opened 13 July '13 contained 1 dead larva, remainder empty
			Aug.	64·9	45·6	—	2	28 ,,	44		
			Sept.	63·2	45·7	—	1	3 Sept. '12	50		
							2	6 ,,	53		
							6	17 Oct. '12	94		
							1	30 ,,	107		
							2	8 Nov. '12	116		
							2	4 Feb. '13	204		
							1	9 ,,	209		
							3	5 Mar. '13	233		
							3	emerged subsequently	say 240		

* No record of temperature or humidity kept subsequently to Sept. 1912.

† Taken out of cocoons 6 Sept. '12.

NOTE. No accurate figures of mortality can be given.

TABLE XLI. *Cocoons* C. gallinae. *Eggs laid by adults fed on human blood; larvae reared and cocoons spun in Incubator 75 Wet; cocoons then removed to various situations.*

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred	Temperature	Humidity	Date of emergence of fleas	No. of days in cocoon	Average	Mortality	Remarks
25 June '12	14	Incubator 75 Dry	June 75·8 July 76·2 Aug. 75·0	·54 ·64 ·56	8 8 July 3 13 ,, 1 24 Aug.	13 18 60	18	7 %	6 larvae emerged from cocoons, 5 pupated and fleas emerged, 1 failed to pupate Cocoons opened 5 Sept. and found to be empty, "false" cocoon
,,	14	Incubator 93 Wet	95·9	·70	1 2 July	7	—	85 %	1 larva emerged from its cocoon but successfully pupated and emerged Remaining cocoons opened 4 Sept., 11 dead pupae, 1 dead larva, 1 empty "false" cocoon
28 June	14	Incubator 93 Dry	93·0	·55	2 8 July	10	—	(Total) 93 % (In cocoon) 5 %	5 larvae emerged from their cocoons but pupated after a few days. Pupae subsequently dried up Remaining cocoons opened 4 Sept., 7 dead pupae, 1 dead larva
,,	11	Cellar	max. min. June 56·5 55·6 July 60·1 59·3 Aug. 57·5 56·5	·93 ·93 ·93	4 26 July 1 3 Aug. 4 9 ,, 2 6 Sept.	28 36 42 70	41	Nil	2 larvae emerged from cocoons but pupated Remaining cocoons opened 6 Sept., 2 living fleas found
2 July	11	Beehive	July 73·4 55·4 Aug. 64·9 45·6 Sept. 63·2 45·7	— — —	1 15 July 4 26 ,, 1 2 Aug. 1 9 ,, 1 24 ,, 1 3 Sept. 1 6 ,,	13 24 31 38 53 63 66	36	(Total) 9 % (In cocoon) Nil	1 larva emerged from its cocoon and died

TABLE XLII. *Cocoons* L. musculi. *Larvae taken from breeding cages, cocoons spun in Incubator 75 Wet (Temperature 75° F., Humidity ·85), and afterwards removed to various situations.*

Date on which cocoons were placed under test conditions	No. of cocoons	Place to which cocoons were transferred	Temperature	Humidity	Date of emergence of fleas	No. of days in cocoon	Average	Mortality	Remarks
18 May '12	24	Iucubator 75 Wet	May 75·6 June 74·9 July 75·0 Aug. 74·3	·86 ·83 ·86 ·81	1 28 May 11 31 ,, 1 3 June 1 24 Aug. 1 30 ,,	10 13 16 98 104	24	37 %	Remainder of cocoons opened 5 Sept., 1 dead flea, 6 dead pupae, 2 dead larvae
,,	24	Incubator 93 Wet	May 95·1 June 94·5 July 95·2 Aug. 94·2	·75 ·77 ·74 ·75	None emerged	—	—	87 % (at least)	Cocoous opened 4 Sept., 20 dead larvae, 1 dead pupa, 2 resting larvae (109 days) Resting larvae and remaining cocoon transferred to Incubator 75 Wet, both larvae died, cocoon a "false" one
,,	24	Cellar	max. min. May 54·2 53·2 June 56·4 55·6 July 60·1 59·3	 ·93 ·93 ·93	7 18 June 8 27 ,, 3 5 July 1 15 ,,	31 40 48 58	38	Nil	2 cocoons opened 4 Sept., 2 living pupae, which subsequently died (109 days) Remaining cocoons opened and found empty, "false" cocoons
12 July	25	Incubator 75 Wet	75·0	·88	20 24 ,, 4 28 ,,	12 16	13	Nil	Remaining cocoon opened 5 Sept. contained living pupa (55 days)
,,	25	Incubator 75 Dry	July 76·2 Aug. 75·0	·64 ·56	1 19 ,, 12 24 ,, 6 27 ,, 3 30 ,, 2 7 Aug.	7 12 15 18 26	14	Nil	Remaining cocoon opened 5 Sept. empty, "false" cocoons
,,	25	Incubator 93 Dry	July 93·0 Aug. 93·0	·57 ·54	None emerged	—	—	60 % (at least)	Cocoons opened 4 Sept., 12 dead larvae, 2 dead pupae, 2 resting larvae, 1 shrunken larva but still fresh and moist, 1 empty 7 cocoons and 2 resting larvae transferred to Incubator 75 Wet, the larvae died and the cocoons proved to be empty (? "false")

,,	25	Incubator 93 Wet	95·2	·74	None emerged		—	—	100 %	Cocoons opened 10 Sept., 14 dried up larvae, 6 dried up pupae, 5 dried up fleas
			max. min.							
,,	25	Cellar	July 60·1 59·3	·93	5	1 Aug.	20	29	Nil	Remaining cocoons opened 6 Sept., 1 living flea, 1 living pupa, 3 empty, "false" cocoons (56 days)
			Aug. 57·5 56·5	·93	11	9 ,,	28			
			Sept. 56·0 54·3	·92	3	13	32			
					1	24 ,,	43			
					1	6 Sept.	56			
,,	25	Lab. Cupboard	July 68·5 62·1	·79	5	27 July	15	19	Nil	Remaining cocoons opened 6 Sept., 1 resting larva (56 days)
			Aug. 63·3 56·3	·84	8	30 ,,	18			
					8	2 Aug.	21			
					3	9 ,,	28			
,,	25	Warm Cupboard	July 67·3	·71	7	26 July	14	24	Nil	Two cocoons opened 5 Sept., 10 empty, 1 living pupa, 1 resting larva (55 days), subsequently pupated and flea emerged 28 Sept., remaining cocoons "false"
			Aug. 64·5	·71	5	30 ,,	18			
					5	3 Aug.	22			
					1	7 ,,	26			
					1	19 ,,	38			
					1	28 ,,	47			
					1	30 ,,	49			
					1	28 Sept.	78			
,,	25	Beehive	July 73·4 55·4	—	4	26 July	14	21	Nil	Cocoons opened 6 Sept., 1 resting larva (56 days), 2 empty, "false" cocoons
			Aug. 64·9 45·6	—	13	2 Aug.	21			
					4	9 ,,	28			
					1	12 ,,	31			

TABLE XLIII. *Retarded emergence from cocoons* C. fasciatus; *full grown larvae taken from the breeding cages and placed with food to complete their development in Incubators 75 Wet and 85 Wet respectively.*

Date 1911	No. of larvae	Receptacle and food	Place	Date after which emergencies were noted	Temperature	Humidity	Number of days from date when full grown larvae were taken from the cages
27 Jan. and 4 Mar.	120 to 150	Card Jar B.S. Rag	Incubator 75 Wet	May			2 fleas took 46
							4 ,, 51
							4 ,, 54
							4 ,, 58
							4 ,, 62
							7 ,, 65
							3 ,, 68
							4 ,, 71
							3 ,, 75
							1 ,, 83
17 Mar.	About 100	,,	,,	,,	Mar. 74·3	·76	1 ,, 49
					April 75·2	·78	2 ,, 52
					May 74·9	·85	5 ,, 55
					June 75·8	·86	1 ,, 56
					July 76·3	·85	11 ,, 59
					Aug. 75·0	·80	14 ,, 63
							13 ,, 66
							5 ,, 70
							5 ,, 74
							2 ,, 76
							1 ,, 88
							1 ,, 95
							1 ,, 102
							1 ,, 105
							1 ,, 131
							1 ,, 151
22 Mar.	,,	,,	,,	,,			2 ,, 56
							4 ,, 61
							2 ,, 69
							2 ,, 71
							3 ,, 117
8 Mar.	,,	,,	Incubator 85 Wet	,,	Mar. 83·7	·71	5 ,, 54
					April 84·0	·72	3 ,, 55
					May 84·0	·76	3 ,, 57
					June 84·0	·80	16 ,, 61
					July 85·1	·83	17 ,, 63
					Aug. 84·7	·81	10 ,, 65
							6 ,, 68
							6 ,, 71
							5 ,, 73
							5 ,, 75
							1 ,, 77
							1 ,, 82
							1 ,, 84
							1 ,, 86
							1 ,, 90
							1 ,, 92
							1 ,, 108
							2 ,, 114
							1 ,, 121
							1 ,, 127
							3 ,, 131
							1 ,, 141
							1 ,, 149

ii. *Influence of immersion in water upon the vitality of Cocoons.* Ct. canis (Table XLIV).

An attempt was made to ascertain what powers, if any, fleas might possess of surviving inundation. The cocoon stage seems to afford the only chance of fleas being able to survive actual flooding of their habitat. A plentiful supply of the cocoons of *Ct. canis* induced the selection of this species for a trial. The larvae were allowed to spin at the bottom of card jars and, after allowing a few days for the silk to harden, the loose sand was emptied out and water poured in until the cocoons were thoroughly submerged.

The water was poured off from the various jars after periods of half an hour, three quarters of an hour, one hour, 12 hours and one week; they were then placed to dry and the fleas allowed to emerge in the laboratory cupboard. As the trial took place during August and September 1911, emergence would be in response to natural conditions of heat and moisture apart from the wetting.

It will be seen that the cocoons of *Ct. canis* easily withstood 12 hours' soaking but were destroyed by a week's submergence. Too much reliance must not be placed on the difference in the number of emergencies in the different experiments as the numbers put in were not accurately counted, but only roughly estimated by dividing a large batch of larvae.

TABLE XLIV. *Immersion Test. Cocoons* Ct. canis.

Date 1911	Approximate number	Period under water	Emergence
1 Aug.	100	half-an-hour	98 fleas on 17 Aug. 2 ,, 30 ,, 5 ,, 28 Sept.
1 ,,	100	three-quarters of an hour	80 ,, 17 Aug. 12 ,, 30 ,, 1 ,, 28 Sept.
1 ,,	100	one hour	66 ,, 15 Aug. 15 ,, 30 ,, 6 ,, 28 Sept.
1 ,,	100	12 hours	62 ,, 17 Aug. 1 ,, 30 ,, 3 ,, 28 Sept.
10 ,,	100	one week	No emergence; two opened contained 1 dried up flea, 1 dried up pupa

iii. *Influence of external conditions at different periods of larval existence upon the duration of the cocoon stage* C. fasciatus.

Experiments were undertaken with a view to discover if the length of the resting period of the larvae of *C. fasciatus* within the cocoon was influenced by changes in the conditions of heat and humidity during the active period of larval life, and also to ascertain if possible at what period of growth the larvae could be most readily influenced.

Two batches of larvae were sorted out from a cage, one judged to be about half grown and the other ready to spin their cocoons. Both lots were subjected to similar treatment but otherwise kept apart, they are referred to as "full grown" and "half grown" respectively. These batches were subdivided, one half of each batch being allowed to feed and spin in incubator 75 Wet while the other half completed its development to the cocoon stage in receptacles kept in the cage from which they had been taken.

In both series of experiments the cocoons as formed were further separated into two batches, one batch of each lot being transferred to incubator 93 Dry and the other being allowed to remain where the larvae had spun. There are therefore eight records to follow up, viz. four batches in incubator 93 Dry, consisting of cocoons from "half grown" larvae spun in the cage and incubator 75 Wet and from "full grown" spun in the cage and incubator 75 Wet: two batches, one from "half grown" and one from "full grown" larvae maintained in incubator 75 Wet throughout and a similar pair kept in the cage.

The drastic conditions prevailing in incubator 93 Dry produced such a high mortality that the experiment more or less failed of its original purpose and a second series of trials were started on the same lines with the exception that incubator 93 Wet was substituted for 93 Dry.

A conclusion which may apparently be gleaned from the results of the first series is that the transference of "half grown" larvae from the cages to incubator 75 Wet is an unfavourable preparation for a higher temperature and drier atmosphere in the cocoon stage (compare batches B and D). I think further it may be taken as settled that a rise in temperature during active larval life, such as removal from the cage to incubator 75 Wet, does not act as a stimulus to lengthen the cocoon period. In fact it seems that the moderate conditions in incubator 75 Wet induce the individuals to curtail their resting period and to develop and emerge after a comparatively short rest. Hot dry conditions appear to inhibit the development of individuals predisposed to a long rest but are not necessarily fatal, provided a reduction in temperature occurs within three or four months. The cage conditions on the other hand allow full scope for any natural predisposition of the species for a long cocoon period.

It is possible that extremes of climate may only control the prevalence of the adults of this species by rendering a distributed emergence impossible and inducing a condensed periodic one in its place.

The results of the second series, while fully in accord with the above conclusions, tend to support the phenomena brought to light in the monthly cocoon tests with this species, Table XXXIII; that this species has a fluctuating, or periodic, constitution as regards its powers of endurance. Allowance must however be made for the difference in incubator conditions in winter and summer brought to light in the newly hatched larvae trials (see footnote on p. 459 in reference to humidity conditions in incubators).

FIRST SERIES. *"Half grown" larvae of* C. fasciatus *taken from cage and allowed to finish feeding and spin their cocoons in Incubator* 75 *Wet (temperature about* 75° *F., humidity about* ·70).

NOTE. The numbers giving the days spent in the cocoon do not increase in exact sequence in all cases owing to the fact that the cocoons were transferred in batches and the fleas as they emerged were presumed to have come from the earliest available batch.

Batch A left in Incubator 75 Wet. Temperature about 75° F.
Humidity about ·65 to ·70.

Date	Number of cocoons	Emergence of fleas	Approximate number of days in cocoon	Number of days in cocoon calculated from average date given in col. 1
22—29 Nov. '11	27	2 on 28 Nov.	6	4
(average date		2 1 Dec.	9	7
24 Nov.)		8 5 ,,	13	11
		9 11 ,,	{6 16 {3 19	17
		2 12 ,,	17	18
		1 11 Jan.	47	48
		1 23 ,,	55	60

2 cocoons opened 4 July '12 found empty ("false" cocoons).

Batch B transferred to Incubator 93 Dry. Temperature about 93° F.
Humidity about ·56 to ·60.

Date	Number of cocoons	Emergence of fleas	Number of days in cocoon
22—29 Nov. '11	27	(None)	—

On the 16 March '12, 19 cocoons were opened and found to contain 13 dead fleas, 5 dead larvae, 1 resting larva.

The remaining cocoons and 1 resting larva were transferred to Incubator 75 Wet; the larva died.

On the 8 July '12, all these cocoons were opened and found to contain dried up larvae.

FIRST SERIES. *"Half grown" larvae of* C. fasciatus *taken from cage and allowed to finish feeding and to spin cocoons in the cage.*

Batch C left in Cage.

Date	Number of cocoons	Emergence of fleas	Approximate number of days in cocoon	Number of days in cocoon calculated from average date given in col. 1
13 Dec. '11—	30	1 on 9 Jan. '12	say 27	16
19 Jan. '12		3 8 Feb.	,, 57	46
(average date		1 26 March	,, 103	92
24 Dec.)		1 1 April	,, 109	98
		1 23 ,,	,, 131	120
		1 27 ,,	,, 135	124
		3 20 June	,, 189	178
		4 1 July	,, 191	189
		1 3 ,,	,, 190	191
		1 10 Aug.	,, 221	229
		1 13 ,,	,, 224	232
		3 9 Sept.	,, 251	259
		1 15 ,,	,, 257	265

Remaining cocoons opened 25 July '13, all were empty except two which contained living larvae that had been resting for a period of from 563 to 590 days.

Batch D transferred to Incubator 93 Dry. Temperature about 93° F. Humidity about ·56 to ·60.

Date	Number of cocoons	Emergence of fleas	Number of days in cocoon
13 Dec. '11—9 Jan. '12	30	1 on 20 Dec. '11	say 7

On 16 March '12, after a period of about 76 days, 6 cocoons were opened and found to contain 1 dead flea, 1 dead larva, 4 resting larvae.

The remaining cocoons and resting larvae were transferred to Incubator 75 Wet and there emerged

		Total number of days in cocoon including those spent in incubator 93 Dry
2 fleas on 3 April	18 days at 75° F., Humidity ·79	94
1 flea 6 ,,	21 ,, ,,	97
2 fleas 8 ,,	23 ,, ,,	99
1 flea 11 ,,	26 ,, ,,	102
1 ,, 19 ,,	34 ,, ,,	114

Remaining cocoons opened 3 July '12 contained 5 dried up fleas, 1 dried up larva, 14 empty cocoons ("false" cocoons[1]).

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[1] The large number of "false" cocoons in these high temperature trials is accounted for by the larvae emerging and dying outside the cocoons where they become brittle and break into unrecognisable fragments.

First Series. *“Full grown” larvae of* C. fasciatus *taken from cage and allowed to finish feeding and to spin their cocoons in Incubator 75 Wet (temperature about 75° F., humidity about ·70).*

Batch A left in Incubator 75 Wet. Temperature about 75° F. Humidity about ·65 to ·70.

Date	Number of cocoons	Emergence of fleas	Number of days in cocoon
18 Nov. '11	31	6 on 28 Nov. '11	10
		4 1 Dec. '11	13
		1 5 ,,	17
		2 16 ,,	28
		2 1 Jan. '12	44
		2 4 ,,	47
		1 6 ,,	49
		2 8 ,,	51
		4 9 ,,	52
		1 11 ,,	54
		1 12 ,,	55
		2 15 ,,	58
		1 23 ,,	66
		2 26 ,,	69

Batch B transferred to Incubator 93 Dry. Temperature about 93° F. Humidity about ·56 to ·60.

Date	Number of cocoons	Emergence of fleas	Number of days in cocoon
18 Nov. '11	31	3 on 25 Nov. '11	7
		1 1 Dec. '11	13

On the 16 March '12, after 119 days in Incubator 93 Dry, 6 cocoons were opened and found to contain 3 dead fleas, 3 resting larvae.

The resting larvae and balance of the cocoons were transferred to Incubator 75 Wet and there emerged

			Total no. of days in cocoon including 119 spent in Incubator 93 Dry
3 fleas on 1 April '12	3	16 days at 75° F., Humidity about ·80	135
6 ,, 3 ,,	6	18 ,, ,, ,,	137
4 ,, 6 ,,	4	21 ,, ,, ,,	140
1 flea on 8 ,,	1	23 ,, ,, ,,	142

Cocoons opened 3 July '12, 2 dried up fleas, 2 dried up pupae, 4 dried up larvae.

First Series. *"Full grown" larvae of* C. fasciatus *taken from cage and allowed to finish feeding and to spin in the breeding cage.*

Batch C left in Cage.

Date	No. of cocoons	Emergence of fleas	Approximate no. of days in cocoon	No. of days in cocoon calculated from average date given in col. 1
19 Nov.— 1 Dec. '11 (average date 25 Nov.)	32	1 on 28 Nov. '11	say 9	3
		1 20 Dec. '11	,, 31	25
		1 13 Jan. '12	,, 55	49
		2 23 April '12	,, 144	150
		1 27 ,,	,, 148	154
		1 24 May '12	,, 175	184
		2 20 June '12	,, 202	208
		1 1 July '12	,, 213	219
		1 3 ,,	,, 215	221
		3 26 ,,	,, 238	244
		1 8 Aug. '12	,, 251	257
		3 9 Sept. '12	,, 283	289
		4 15 ,,	,, 289	299
		1 19 Jan. '13	,, 415	421

3 fleas, date of emergence unrecorded, found dead 25 July '13

Remaining cocoons opened 25 July '13 contained 1 dead and 3 living larvae; these latter had "rested" from 571 to 613 days.

Batch D transferred to Incubator 93 Dry. Temperature about 93° F.
Humidity about ·56 to ·60.

Date	Number of cocoons	Emergence of fleas	Number of days in cocoons
19 Nov.—1 Dec. '11	32	None	—

On 16 March '12, after about 112 days in Incubator 93 Dry, 3 cocoons were opened and found to contain resting larvae.

The resting larvae and remaining cocoons were transferred to Incubator 75 Wet and there emerged

		Total no. of days in cocoon including those (112 approximately) spent in Incubator 93 Dry
3 fleas on 1 April	16 days at 75° F., Humidity ·80 to ·86	128
3 ,, 3 ,,	18 ,, ,, ,,	130
2 ,, 6 ,,	21 ,, ,, ,,	133
2 ,, 8 ,,	23 ,, ,, ,,	135
1 flea on 11 ,,	26 ,, ,, ,,	138
3 fleas on 16 ,,	31 ,, ,, ,,	143
1 flea on 19 ,,	34 ,, ,, ,,	146
1 ,, 24 ,,	39 ,, ,, ,,	151
1 ,, 16 June	92 ,, ,, ,,	204

Remaining cocoons opened 3 July '12 contained 2 dried up fleas, 1 dried up pupa, 3 dried up larvae, 9 "false" cocoons.

SECOND SERIES. *"Half grown" larvae of* C. fasciatus *taken from breeding cage and allowed to finish feeding and to spin cocoons in Incubator* 75 *Wet.*

Batch A left in Incubator 75 Wet. Temperature about 75° F. Humidity about ·80 to ·86.

Date	No. of cocoons	Emergence of fleas	Approximate no. of days in cocoon	No. of days in cocoon calculated from average date given in col. 1
18—26 March '12 (average date 22 March)	31	2 on 1 April '12	say 14	10
		6 3 ,,	,, 16	12
		3 8 ,,	,, 20	17
		5 11 ,,	,, 20	20
		1 16 ,,	,, 25	25
		4 23 ,,	,, 32	32
		1 27 ,,	,, 36	36
		1 30 ,,	,, 35	39
		1 6 May '12	,, 41	45
		2 16 ,,	,, 51	55
		2 21 ,,	,, 56	60
		1 24 ,,	,, 59	63
		1 28 ,,	,, 63	67

Cocoons opened 4 July '12, 1 "false" cocoon.

Batch B transferred to Incubator 93 Wet. Temperature about 93° F. Humidity about ·67.

Date	Number of cocoons	Emergence of fleas	No. of days in cocoon
18—26 March '12	32	2 on 28 March '12	say 10

Cocoons opened 2 July '12 contained 22 dried up fleas, 7 dried up larvae, 1 "false" cocoon.

SECOND SERIES. *"Half grown" larvae of* C. fasciatus *allowed to finish feeding and to spin cocoons in the breeding cage.*

Batch C left in Cage.

Date	No. of cocoons	Emergence of fleas	Approximate no. of days in cocoon		No. of days in cocoon calculated from average date given in col. 1
18 April— 8 May '12 (average date 24 April)	18	4 on 24 May	say 36		30
		2 20 June	,, 63		57
		1 3 July	,, 76	Cocoon opened and living flea emerged	70
		2 10 Aug.	,, 114		118
		2 13 ,,	,, 117		121
		1 1 Sept.	,, 127		130
		*2 9 ,,	,, 135	Cocoons opened and living fleas emerged	138

10 cocoons opened 9 Sept. '12 contained 1 dead flea, 2 living fleas, 2 dead larvae, 1 living larva which subsequently died.

Batch D transferred to Incubator 93 Wet. Temperature about 93 to 95° F.
Humidity about ·70 to ·75.

Date	Number of cocoons	Emergence of fleas	No. of days in cocoon
18 April—2 May '12	18	none	—

Cocoons opened 2 July '12 contained 2 dried up fleas, 4 dried up pupae, 4 resting larvae. The resting larvae were transferred to Incubator 75 Wet to see if they would continue their development, they died without becoming pupae.

Second Series. *"Full grown" larvae of* C. fasciatus *taken from breeding cage and allowed to spin cocoons in Incubator 75 Wet.*

Batch A left in Incubator 75 Wet. Temperature about 75° F. Humidity about ·80 to ·85.

Date	No. of cocons	Emergence of fleas	Approximate no. of days in cocoon	No. of days in cocoon calculated from average date given in col. 1
14—19 March '12	33	1 on 22 March	say 8	6
(average date		9 26 ,,	,, 12	10
16 March)		6 29 ,,	,, 15	13
		4 1 April	,, 18	16
		2 21 May	,, 63	66
		1 24 ,,	,, 66	69
		1 3 June	,, 76	79
		1 8 ,,	,, 81	85

Cocoons opened 4 July '12 contained 5 dried up larvae.

Batch B transferred to Incubator 93 Wet. Temperature about 93° F.
Humidity about ·67 to ·70.

Date	No. of cocoons	Emergence of fleas	Approximate no. of days in cocoon	No. of days in cocoon calculated from average date given in col. 1
14—19 March '12	33	1 on 22 March	say 8	6
(average date		6 26 ,,	,, 12	10
16 March)		1 28 ,,	,, 14	12
		2 1 April	,, 17	16
		1 8 ,,	,, 24	23
		2 12 ,,	,, 28	27

Cocoons opened 2 July '12 contained 7 dried up fleas, 11 dried up larvae.

Second Series. *"Full grown" larvae of* C. fasciatus *allowed to spin their cocoons in the breeding cage.*

Batch C left in Cage.

Date	No. of cocoons	Emergence of fleas	Approximate no. of days in cocoon	No. of days in cocoon calculated from average date given in col. 1
19 March—	21	2 on 23 April	say 35	28
8 April '12		3 27 ,,	,, 39	32
(average date		2 2 May	,, 38	37
26 March)		1 1 July	,, 98	97
		1 3 ,,	,, 100 Cocoon opened	99
		1 8 Aug.	,, 136	135
		1 9 Sept.	,, 168	167
		1 10 Oct.	,, 199	198
		2 26 ,,	,, 213	214

Remaining cocoons opened 25 July '13, one contained a living larva which had been resting between 473 and 493 days, remaining cocoons empty.

Batch D transferred to Incubator 93 Wet. Temperature about 93° F.
Humidity about ·70 to ·75.

Date	Number of cocoons	Emergence of fleas	Approximate no. of days in cocoon
19 March—8 April '12	21	1 on 18 April	say 30
		1 5 Aug.	,, 96

Cocoons opened 2 July '12 contained 6 dried up fleas, 4 dried up pupae, 9 dried up larvae, 1 resting larva. The resting larva was transferred to Incubator 75 Wet, 2 July. This larva pupated on 30 July. A flea emerged on 5 Aug., say 90 days in Incubator 93 Wet. This individual therefore continued resting without a cocoon in Incubator 75 Wet for 28 days and emerged as adult in 6 days. Total 96 days.

iv. *Significance of "Hard" and "Soft" cocoons of* C. fasciatus. Experiments were made in order to ascertain whether those individuals that formed hard cocoons deferred emergence for a longer period than those whose cocoons were of the softer type. Two sets of experiments were performed, one in which sand was used and one in which house dust replaced the sand to test whether the nature of the attached fragments had any influence upon the character of the cocoon.

When the larvae of *C. fasciatus* are given finely sifted house dust (sweepings of floors) in place of silver sand the silk of their cocoons differs from that of those formed in sand. The cocoons are tougher and the silk is whiter and more papery in appearance, and is less suggestive of thin glue that has been allowed to harden, than is the case when grains of sand are embedded in place of dust.

It seems possible that this variation is in part, perhaps largely, due to the small size of the particles of dust and their more absorbent nature producing a different action in the setting of the silk. Sand is composed of larger particles which are individually non-absorbent, and this no doubt delays the drying and affords an opportunity for the threads of mucilage to coalesce into larger masses before drying takes place[1].

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[1] My assistant Mr J. H Turner states that he has noticed that the "hard" cocoons generally have smaller grains of sand attached than the "soft"; presumably such a difference must rest on a selective act on the part of the larvae when spinning their cocoons. There is also a well marked difference between the individual cocoons of *C. fasciatus* apart from the material worked into them, and although I have not opened sufficient examples to make any definite generalisation, the cocoons of the different species show marked divergencies when all are spun in sand. Cocoons of *X. cheopis* are softer as well as tougher than those of *C. fasciatus*, approximating towards the type of *P. irritans* which is composed of a felt of actual silk threads with the extraneous matter attached on the outer side.

A number of larvae of *C. fasciatus* were taken from the cages and allowed to spin in incubator 75 Wet, in the case of one series in sand and of the other in dust. The stronger cocoons among those spun in dust are more correctly described as "firm" than "hard"; for the sake of uniformity, however, the latter term has been used in both series of experiments. The question as to whether an individual cocoon should be regarded as "soft" or "hard" was decided by pressing upon the cocoon with the side of a fine needle, near the point. Those which yielded were designated as "soft," those which resisted as "hard." That the stage of development of the insect has nothing to do with the consistence was shown by the fact that some of the resistant cocoons were found to be empty. When covered with sand the hardness was more extreme, quite considerable pressure being required to crush empty ones.

The cocoons were allowed to remain in incubator 75 Wet for a few days after spinning and were then sorted out into batches of "hard" and "soft" respectively and then transferred to incubator 93 Dry. In the sand series some cocoons of each class were kept in incubator 75 Wet as a control. A few examples of those spun in dust, opened to test the reliability of the sorting, gave the following particulars:

8 "soft" showed	9 "hard" showed
1 pupa	3 pupae
1 resting larva	3 resting larvae
6 empty (fleas emerged)	3 empty (fleas emerged)

While the results obtained support the view that the larvae in "hard" cocoons are better able to resist conditions of heat and drought than those in the "soft," it is not clear that the *solidity* of the cocoon is the only factor. It will be noticed that there was a higher mortality among the "soft" than the "hard" in incubator 75 Wet, sand series, which suggests that "hard" cocoons may be associated with individuals of greater vitality and that the question is not merely one of the type of cocoon or a special adaptation for resting. It is, however, true that the resting stage is longer in the hard cocoons, which favours the theory that the greater solidity of these cocoons diminishes the risks of a deferred emergence.

These experiments also bring into special prominence the inhibitory action of incubator 93 Dry with regard to emergence, which offers a contrast to the results obtained in incubator 75 Wet, where the average duration of the cocoon period is very short in comparison.

"*Hard*" *and* "*Soft*" *Cocoons* C. fasciatus.

Cocoons spun in dust. Larvae taken from cages and allowed to spin their cocoons in finely sifted house dust in Incubator 75 *Wet and then transferred to Incubator* 93 *Dry* (*humidity about* ·56 *to* ·60).

"Soft" batch.

Date	Number	Fleas emerged	No. of days in cocoon
6 Nov. '11	22	5 on 21 Nov.	15
		7 25 ,,	19

On 16 March '12 after 131 days in Incubator 93 Dry, 2 cocoons were opened and 1 resting larva, 1 empty ("false" cocoon), were found.

The remaining cocoons and the resting larva were transferred to Incubator 75 Wet. The larva died. Fleas emerged from cocoons as under:

		Total no. of days in cocoon, including 131 days in Incubator 93 Dry
1 flea emerged 1 April	16 days at 75° F., Humidity ·79	147
,, ,, 16 ,,	31 ,, ,, ,,	162
,, ,, 23 ,,	38 ,, ,, ,,	169

On 4 July '12 remaining cocoons opened, 5 dried up larvae found.

"Hard" batch.

Date	Number	Fleas emerged	No. of days in cocoon
6 Nov. '11	29	6 on 24 Nov.	18
		1 27 ,,	21

On 16 March '12, 2 cocoons were opened, both contained resting larvae; these together with the remaining cocoons were transferred to Incubator 75 Wet and there emerged

		Total no. of days in cocoon including 131 days in Incubator 93 Dry
2 fleas emerged 1 April	16 days at 75°F., Humidity ·79	147
8 ,, ,, 6 ,,	21 ,, ,, ,,	152
1 flea ,, 8 ,,	23 ,, ,, ,,	154
2 fleas ,, 11 ,,	26 ,, ,, ,,	157
1 flea ,, 30 ,,	45 ,, ,, ,,	176

On 4 July cocoons opened, contained 3 dried up fleas, 3 dried up larvae.

From a few of the unsorted cocoons which were left in Incubator 75 Wet, when the others were transferred to Incubator 93 Dry, fleas emerged as follows:

Date	Number	Fleas emerged	No. of days in cocoon
6 Nov. '11	Number unknown	1 on 21 Dec. '11	45
		2 24 ,,	48
		1 12 Jan. '12	67
		1 16 ,,	71
		4 18 ,,	73

“Hard” and “Soft” Cocoons C. fasciatus.

Cocoons spun in sand. Larvae taken from cages and allowed to spin their cocoons in fine silver sand in Incubator 75 Wet and then transferred to Incubator 93 Dry (humidity about ·56 to ·60).

“Soft” batch.

Date	Number	Fleas emerged	No. of days in cocoon
5 Nov. ’11	24	1 on 16 Nov. ’11	11

On 16 March ’12, 8 cocoons were opened and found to contain 1 dead flea, 4 dead larvae, 3 resting larvae.

The resting larvae and the remaining cocoons were transferred to Incubator 75 Wet. (Two of the larvae died, one pupated and a flea duly emerged.)

4 fleas emerged 6 April, 132 days at 93° F., Humidity ·56 to ·60; 21 days at 75° F., Humidity ·79. Total 153 days.

Remaining cocoons opened 3 July ’12 contained 3 dried up fleas, 6 dried up larvae, 2 “false” cocoons.

“Hard” batch.

Date	Number	Fleas emerged	No. of days in cocoon
5 Nov. ’11	39	none	—

On 16 March ’12, after 132 days in Incubator 93 Dry, 11 cocoons were opened and found to contain 2 dead fleas, 7 larvae somewhat shrunken and devoid of movement but not discoloured or dried, 2 resting larvae which subsequently pupated and produced adults.

The resting larvae and remaining cocoons were transferred to Incubator 75 Wet.

		Total number of days in cocoon including 132 days in Incubator 93 Dry
2 fleas emerged 3 April	18 days at 75° F., Humidity ·79	150
2 ,, 6 ,,	21 ,, ,, ,,	153
4 ,, 8 ,,	23 ,, ,, ,,	155
2 ,, 11 ,,	26 ,, ,, ,,	158
1 flea emerged 16 ,,	31 ,, ,, ,,	163
1 ,, 27 ,,	42 ,, ,, ,,	174

Cocoons opened 3 July ’12 contained 3 dried up fleas, 7 dried up larvae[1].

“Hard” and “Soft” Cocoons C. fasciatus.

Cocoons spun in sand. Larvae taken from cages and allowed to spin their cocoons in fine silver sand in Incubator 75 Wet and left under these conditions for the fleas to emerge (remainder of batch of cocoons used for experiments in previous table).

“Soft” batch.

Date	Number	Fleas emerged	No. of days in cocoon
5 Nov. ’11	24	1 on 13 Nov. ’11	8
		1 16 ,,	11
		4 18 ,,	13
		2 19 Dec. ’11	44
		3 24 ,,	49
		1 1 Jan. ’12	57

Cocoons opened 3 July ’12 contained 8 dried up larvae[1].

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[1] The record for “hard” and “soft” cocoons spun in sand is incomplete, no record was made on July 3rd 1912 of the number of empty or “false” cocoons in the “hard” batch in Incubator 93 Dry or in the “soft” batch in Incubator 75 Wet.

"Hard" batch.

Date	Number	Fleas emerged		No. of days in cocoon
5 Nov. '11	39	1	on 13 Nov. '11	8
		1	16 ,,	11
		2	25 ,,	20
		1	19 Dec. '11	44
		5	22 ,,	47
		2	23 ,,	48
		2	24 ,,	49
		2	26 ,,	51
		3	27 ,,	52
		3	28 ,,	53
		4	1 Jan. '12	57
		2	4 ,,	60
		2	8 ,,	64
		1	9 ,,	65
		2	11 ,,	67
		1	29 ,,	85
		1	11 Feb. '12	98

Cocoons opened 3 July '12, 4 empty, "false" cocoons.

4. ADULTS (Tables XLV to LIX).

i. *Duration of Life unfed.*

P. irritans (Tables XLV and L). The experiments with adult specimens of *P. irritans* just emerged from their cocoons and unfed are too few to be conclusive; the results obtained suggest, however, that the species cannot survive long without feeding if exposed to warmth or heat, even if the conditions are humid. In cool and moist places, however, a life of more than 100 days was recorded (see Table XLV). Allowing them to burrow free in sand does not appear to favour an extended life.

C. fasciatus (Tables XLVI and L) when kept in paper tubes, cannot compete with *P. irritans* as regards its power of surviving without food. When kept in a paper tube no life of more than 31 days was recorded even in the most favourable situation; but, as already noted in the general remarks on life history, when allowed to burrow in sand an individual survived starvation for 95 days. In less favourable situations there is not much to choose between the species.

X. cheopis (Tables XLVII and L). It does not appear that adults of *X. cheopis* differ very much from *C. fasciatus* in their power of enduring starvation. It is possible that they stand hot and dry conditions a little better, but, to judge from the beehive record, they are quite unsuited for a cold situation. Burrowing in sand would appear to increase their powers of resistance.

Ct. canis (Tables XLVIII and L). This species has powers of endurance about equal to those of *C. fasciatus* when tested by the paper tube method; burrowing free in sand does not seem to appreciably extend its powers of survival unfed.

C. gallinae (Tables XLIX and L). Only a small number were available and these were used for tests in cool situations only. When tested by the paper tube method they show endurance on about the same scale as *C. fasciatus* or *X. cheopis*, but burrowing in sand would appear to make a vast difference to them, one specimen surviving 127 days and showing an endurance equalled only by *P. irritans*.

ii. *Duration of Life when fed.*

(*a*) *for an initial period only.* *P. irritans* and *C. fasciatus* (Tables LI and LII). Newly emerged specimens of these two species were fed for certain periods and then tested as in the previous series. It will be seen from a comparison of Tables XLV and XLVI with LI and LII respectively that, under cool conditions with high humidity, the fact of a flea having previously fed makes little material difference to its powers of endurance, but that under warm to high temperatures with a low humidity, a meal to start with is a very valuable asset.

For example, in case of *P. irritans*, in the cellar, the longest length of life when starved subsequent to a period of feeding was 121 days, while, in case of adults starved from emergence, a life of 126 days was recorded. In incubators 75 Dry and 85 Dry, on the other hand, previous feeding raised the figure obtained for length of life from 5 to 17 and 5 to 12 days respectively.

It is greatly to be regretted that only single individuals of *P. irritans* were available for this test. The consistent increase in length of life recorded as we pass from hot and dry to cool and moist situations may, however, be taken as confirmatory of the trustworthiness of the results.

C. fasciatus. This species, like *P. irritans*, does not gain by feeding prior to starvation; feeding for several days tends to lessen, not increase, their powers of survival and leaves the average total length of life practically unaltered.

Ct. canis (Table LIII). The small trial made with this species cannot be compared with the *P. irritans* and *C. fasciatus* tests, as the specimens were of unknown age, and had already been 24 hours in incubator 75 Wet before the test was made.

(*b*) *At regular intervals. P. irritans.* When fed on man daily, individual specimens of this species have lived for various periods up to 513 days (see Table LIV (*c*)), and, when fed weekly, also over a year if kept under cool humid conditions (see Table LIV (*d*)).

It will be seen from Table LIV that the summer is just as favourable as the winter. Several of the early deaths recorded for this species were due to accident, becoming gummed to the glass bottom of the box by their own dejecta or losing portions of the legs. On a few occasions, deaths have been quite inexplicable; in one instance some six or eight freshly emerged specimens all died within 10 or 12 days, although afforded equal opportunities of feeding with batches that enjoyed extended lives.

Buckland records (*Curiosities of Natural History*, fourth series, p. 123) on the authority of the owner of some performing fleas, a specimen which lived for eighteen months—a period which slightly exceeds the longest life recorded in the present experiments.

C. fasciatus. The number and variety of other experiments on hand prevented the carrying through of cage experiments with this species and *X. cheopis* to test the length of life of these species when free upon their natural hosts. Two or three early attempts failed, owing to paucity of supplies, and it has not been found possible to repeat them. Experiments in which the fleas were fed on rats by the box method, point to the necessity of cool, or at least moderate conditions of temperature (see Table LV, under date of 12th October, 1910, in incubator 85 Wet) and, when not living in close association with the rat, to the need of more frequent chances of feeding than were found necessary for *P. irritans.* The longest life recorded is 106 days, and this is probably nearer to the correct length of time than the average lives—the early deaths which bring down the average being probably those of individuals which never commenced feeding.

iii. *Duration of Life if fed on an alien host.*

C. fasciatus fed on man (Table LVI). When fed on man the average length of life is, on the whole, higher than when fed on rats by the box method, possibly because the feeding being conducted at night while in bed the time was apt to be extended longer than the usual 15 minutes. The 10 deaths in 13 days, recorded in the experiment under date 15th July, 1911, were due to a misadventure and should not be considered when judging results.

X. cheopis. The experiment (Table LVI) shows this species to be better adapted to a human host than *C. fasciatus*, lives of over 70 days being frequent. Observation of the specimens during the course of the experiment provides confirmatory evidence of this, in that they were seen to be very lively and to be feeding vigorously, judging by the full state of their stomachs.

Ct. canis and *Ct. felis.* It will be seen from Table LVII that these two species can exist quite successfully on a diet of human blood —the lives recorded being of considerable extent, as long as 345 and 185 days respectively.

C. gallinae (Table LVII) is also able to live for a considerable period when fed on man. The single specimen captured on the dog lived 224 days after capture.

L. musculi (Table LVII). A certain percentage of individuals of this species will certainly feed on man, the blood was quite visible in previously unfed specimens, but they do not bite freely, as do *X. cheopis* and *C. fasciatus.* Life was only of very short duration and did not exceed 10 days in case of any of the fleas tested.

Spilopsyllus cuniculi (Table LVII). This species feeds much more freely on man than does *L. musculi*; I think all the specimens tried bit, but they are not transparent enough to show blood in their stomachs. As will be seen from the table, their record is consistent with this view.

Attempts to feed *P. irritans* and *Ct. canis* on rats (Table LV) show that the last named species will certainly feed, but, as regards the former, it is somewhat doubtful whether the insects did more than experiment, the lives of those fed upon rats by the box method being no longer than one would expect if kept unfed under the same circumstances.

iv. *Attempts to induce fleas to feed upon material other than the blood of a living animal.*

The experiments in which fleas were given the opportunity of sucking water or feeding on syrup, broth, etc., have not been successful in establishing as a fact whether they do feed, or whether they only obtain a benefit by the moisture in the air obtained by a pad of blotting paper moistened being placed in the box with them. The fleas were observed to jump on the pad and sometimes put down their heads as if to feed, but as the process was only followed with a hand lens and the fleas were kept in a box it is not possible to say whether suction actually took place.

A number of dissections was made of individuals kept under similar conditions to those mentioned above; carmine and other stains, that were successfully used with larvae of fleas and of flies, were mixed with the artificial foods or water, but no trace of the stain was ever found in the gut of the adult flea.

TABLE XLV. *Adult fleas.* P. irritans. *Length of life unfed. Fleas freshly emerged from cocoons, placed in filter paper tubes and buried in sand in various situations.*

Date	No.	Place	Temperature		Humidity	Detail
12 May '11	1	Incubator 85 Wet	83·8		·81	dead in 11 days
12 ,,	1	Incubator 75 Wet	75·1		·91	,, 9 ,,
10 ,,	1	Incubator 85 Dry	84·0		·61	,, 5 ,,
10 ,,	1	Incubator 75 Dry	74·7		·53	,, 5 ,,
15 ,,	1	Warm Cupboard	63·5		·65	,, 6 ,,
			max.	min.		
15 ,,	1	Lab. Cupboard	62·6	54·1	·81	,, 11 ,,
4 Aug. '10	2	,,	74·4	66·0	·74	1 ,, 9 ,, 1 ,, 10 ,,
12 Dec. '10	1	Damp corner of Cellar	47·3	46·0	over ·94	,, 71 ,,
1 Mar. '11	1	,,	51·8	50·3	,, ·93	dead in 126—130 days
27 April '11	2	,,	57·6	56·3	,, ·93	1 dead in 63 days 1 ,, 91 ,,
18 Aug. '11	1	,,	62·9	61·6	,, ·94	escaped after 1 month
19 ,,	3	,,	62·2	61·3	,, ·94	1 dead in 28 days 2 ,, 32 ,,
28 April '11	2	Beehive	69·5	43·1	—	1 ,, 15 ,, 1 ,, 20 ,,

TABLE XLVI. *Adult fleas.* C. fasciatus. *Length of life unfed.* (*a*) *Fleas freshly emerged from cocoons, placed in filter paper tubes and replaced in soil pots in the situations in which they had been reared from cocoons.*

Dates between which the fleas were obtained	No.	Place	Temperature	Humidity	Detail	Longest period of survival, days	Average period of survival, days
17 Aug. '10—	18	Incubator	Dry 84·5	·71	2 dead in 4 days	13	8
28 Sept. '10		85 Wet			1 ,, 6 ,,		
					8 ,, 7 ,,		
					1 ,, 8 ,,		
					1 ,, 9 ,,		
					1 ,, 11 ,,		
					1 ,, 12 ..		
					2 ,, 13 ,,		
					1 lost		

TABLE XLVI.—*Continued.*

Dates between which the fleas were obtained	No.	Place	Temperature	Humidity	Detail	Longest period of survival, days	Average period of survival, days
15 Aug. '10—	13	Incubator	Dry 74·3	·65	4 dead in 5 days	7	6
29 ,,		75 Wet			3 ,, 6 ,,		
					6 ,, 7 ,,		
19 Aug. '10—	17	Laboratory	estimate 60·0	·80	2 ,, 5 ,,	15	10
3 Oct. '10		Cupboard			1 ,, 6 ,,		
					7 ,, 10 ,,		
					1 ,, 11 ,,		
					1 ,, 12 ,,		
					2 ,, 13 ,,		
					2 ,, 14 ,,		
					1 ,, 15 ,,		
			max. min.				
25 Aug. '10—	13	Cellar	58·3 57·3	estimate ·90	2 ,, 7 ,,	17	14
6 Oct. '10					1 ,, 10 ,,		
					2 ,, 12 ,,		
					1 ,, 13 ,,		
					1 ,, 15 ,,		
					1 ,, 16 ,,		
					5 ,, 17 ,,		
1—7 Dec. '10	1	,,	48·7 47·7	·93	1 ,, 6 ,,	—	—
(*b*) *Fleas taken from stock reared in Incubator* 75 *Wet.*							
28 Dec. '10—	12	Cellar	46·5 45·3	·93	2 ,, 17 ,,	31	24
28 Jan. '11					4 ,, 21 ,,		
					4 ,, 28 ,,		
					2 ,, 31 ,,		
28 Dec. '10—	7	Laboratory	53·5 43·2	·85	1 ,, 10 ,,	20	16
17 Jan. '11		Cupboard			2 ,, 14 ,,		
					2 ,, 17 ,,		
					2 ,, 20 ,,		
7 Jan. '11—	10	Beehive	44·3 32·2	—	2 ,, 10 ,,	24	15
31 ,,					3 ,, 13 ,,		
					3 ,, 17 ,,		
					1 ,, 21 ,,		
					1 ,, 24 ,,		
12 Sept. '11	4	Incubator	Dry 75·0	·54	1 ,, 3 ,,	5	4
		75 Dry			2 ,, 4 ,,		
					1 ,, 5 ,,		
12 ,,	4	Incubator	Dry 84·1	·59	4 ,, 3 ,,	—	—
		85 Dry					

TABLE XLVII. *Adult fleas.* X. cheopis. *Length of life unfed. Fleas freshly emerged from cocoons, spun in Incubator* 75 *Wet, placed in filter paper tubes and buried in sand in various situations.*

Date 1911	Number	Place	Temperature max. min.	Humidity	Detail	Longest period of survival, days	Average period of survival, days
7 Oct.	6	Cellar	56·0 54·4	·93	3 dead in 23 days	28	25
					2 ,, 27 ,,		
					1 ,, 28 ,,		
7 ,,	6	Incubator 75 Wet	74·2	·72	2 ,, 7 ,,	13	10
					1 ,, 9 ,,		
					2 ,, 12 ,,		
					1 ,, 13 ,,		
19 ,,	10	,, 75 Dry	74·8	·56	5 ,, 4 ,,	6	5
					4 ,, 5 ,,		
					1 ,, 6 ,,		
19 ,,	10	,, 85 Dry	84·0	·61	1 ,, 2 ,,	5	4
					6 ,, 4 ,,		
					3 ,, 5 ,,		
19 ,,	10	,, 85 Wet	84·2	·80	1 ,, 6 ,,	13	9
					3 ,, 8 ,,		
					3 ,, 9 ,,		
					2 ,, 11 ,,		
					1 ,, 13 ,,		
19 ,,	10	Lab. Cupboard	52·5 49·8	·86	2 ,, 6 ,,	17	12
					4 ,, 12 ,,		
					1 ,, 14 ,,		
					3 ,, 17 ,,		
24 ,,	10	Warm Cupboard	Dry 67·0	·55	4 ,, 4 ,,	6	5
					6 ,, 6 ,,		
24 ,,	10	Beehive	56·2 34·5	—	3 ,, 4 ,,	6	5
					7 ,, 6 ,,		

TABLE XLVIII. *Adult fleas.* Ct. canis. *Length of life unfed. Fleas, freshly emerged from cocoons, reared in Incubator 75 Wet, from larvae taken from the dog's bed. The fleas were placed in filter paper tubes and buried in sand in various situations.*

Date of emergence and commencement of test	No.	Place	Temperature	Humidity	Detail	Longest period of survival, days	Average period of survival, days
7 Nov. '10	5	Incubator 85 Wet	84·0	·71	5 dead in 6 days	—	—
17 ,,	9	,,	84·0	·70	4 ,, 4 ,, 5 ,, 8 ,,	8	6
17 ,,	8	Incubator 75 Wet	74·3	·73	1 ,, 5 ,, 2 ,, 8 ,, 4 ,, 11 ,, 1 ,, 13 ,,	13	9
28 ,,	13	Warm Cupboard	59·8	·60	3 ,, 4 ,, 10 ,, 6 ,,	6	5
7 ,,	5	Cellar (moist corner)	max. min. 45·0 43·7	over ·93	1 ,, 12 ,, 3 ,, 21 ,, 1 ,, 32 ,,	32	21
13 Dec. '10	10	Box (out of doors)	No record, there were several sharp frosts	—	4 ,, 6 ,, 3 ,, 10 ,, 2 ,, 25 ,, 1 ,, 29 ,,	29	13
10 Nov. '10	4	Laboratory Cupboard	54·0 42·8	about ·84	2 ,, 4 ,, 1 ,, 9 ,, 1 ,, 11 ,,	11	6
17 Aug. '11	4	Cellar (moist corner)	Aug. 64·5 63·4 Sept. 60·6 59·5	over ·94 ,, ·93	2 ,, 34 ,, 2 ,, 44 ,,	44	39
21 Sept. '11	10	Incubator 75 Dry	74·7	·51	4 ,, 4 ,, 4 ,, 5 ,, 1 ,, 6 ,, 1 ,, 7 ,,	7	5
21 ,,	10	Incubator 75 Wet	74·4	·73	2 ,, 5 ,, 6 ,, 9 ,, 2 ,, 10 ,,	10	8
21 ,,	10	Incubator 85 Dry	84·6	·56	1 ,, 2 ,, 6 ,, 4 ,, 3 ,, 5 ,,	5	4
21 ,,	10	Incubator 85 Wet	84·7	·77	2 ,, 5 ,, 4 ,, 6 ,, 4 ,, 8 ,,	8	7

TABLE XLVIII—*Continued.*

Date of emergence and commencement of test	No.	Place	Temperature	Humidity	Detail	Longest period of survival, days	Average period of survival, days
21 Sept.' 11	10	Warm Cupboard	64·2	·66	1 dead in 5 days	10	7
					4 ,, 6 ,,		
					3 ,, 7 ,,		
					1 ,, 9 ,,		
					1 ,, 10 ,,		
21 ,,	10	Beehive	67·4 41·4	—	3 ,, 9 ,,	20	14
					3 ,, 12 ,,		
					1 ,, 15 ,,		
					2 ,, 19 ,,		
					1 ,, 20 ,,		
22 ,,	10	Laboratory Cupboard	59·7 51·1	·82	2 ,, 8 ,,	24	14
					1 ,, 11 ,,		
					2 ,, 12 ,,		
					2 ,, 13 ,,		
					1 ,, 17 ,,		
					1 ,, 21 ,,		
					1 ,, 24 ,,		
22 ,,	30	Cellar	Sept. 60·6 59·5	·93	13 ,, 31 ,,	57	35
			Oct. 56·3 54·8	·92	14 ,, 42 ,,		
			Nov. 50·7 48·9	·91	1 ,, 52 ,,		
					1 ,, 54 ,,		
					1 ,, 57 ,,		
Put into 1¼″ ento. box and buried in sand.							
21 ,,	13	Cellar (moist corner)	Sept. 60·6 59·5	over ·93	2 ,, 15 ,,	39	31
			Oct. 56·3 54·8	,, ·92	8 ,, 32 ,,		
					3 ,, 39 ,,		

TABLE XLIX. *Adult fleas.* C. gallinae. *Length of life unfed. Fleas (apparently freshly emerged from cocoon) obtained from empty nest of blue tit, placed in filter paper tubes and kept in sand pots in various situations.*

Date of emergence and commencement of test	No.	Place	Temperature max.	Temperature min.	Humidity	Detail	Longest period of survival, days	Average period of survival, days
13 Feb. '11	4	Beehive	51·7	32·7	—	2 dead in 21 days	27	26
						1 ,, 25 ,,		
						1 ,, 27 ,,		
,,	3	Lab. Cupboard	55·3	45·6	·84	1 ,, 14 ,,	28	20
						1 ,, 19 ,,		
						1 ,, 28 ,,		
,,	6	Cellar	46·9	45·3	·92	1 ,, 5 ,,	45	32
						1 ,, 35 ,,		
						1 ,, 39 ,,		
						2 ,, 45 ,,		
						1 escaped		

Table L. *Adult fleas of various species, length of life unfed. Fleas freshly emerged from cocoons spun in Incubator 75 Wet and kept in the cellar in card jars containing sand for them to burrow in.*

Species	Date of emergence and commencement of the test	Number	Place	Temperature			Humidity	Detail	Longest period of survival
					max.	min.			
P. irritans	20 Dec. '11	12	Cellar					Only one active seen after end of January	84 days
Ct. canis	4 Jan. '12	4	,,	Sept.	60·6	59·5	·93	More than one seen active at end of Feb., all dead by 2 March	58 ,,
				Oct.	56·3	54·8	·92		
				Nov.	50·7	48·9	·91		
X. cheopis	1 Jan. '12	20	,,	Dec.	48·7	47·4	·92	Several seen active on 1 Feb., all dead by 7 Feb.	38 ,,
				Jan.	47·2	45·9	·92		
				Feb.	45·8	44·6	·92		
C. gallinae	1—5 Feb. '12	4	,,	Mar.	49·1	48·1	·93	3 died between 29 May and 1 June, last died 11 June	127 ,,
				Apr.	50·3	49·1	·93		
				May	54·2	53·2	·93		
C. fasciatus	5 Sept. '11	20 to 30	,,	June	56·4	55·6	·93	A number were seen active on 2 Dec. but by the 7th only one feeble individual was to be seen, all were dead by 12 Dec.	about 95 days

TABLE LI. *Adult fleas.* P. irritans. *Length of life unfed after feeding for a period. Fleas freshly emerged were fed for at least one week on human blood and then kept without food in filter paper tubes placed in sand pots in various situations.*

Date of commencement of test	No.	Place	Temperature max.	Temperature min.	Humidity	Total length of life, days	Length of life unfed, days
30 Sept. '10	1	Cellar (moist corner)	50·4	49·2	over ·93	121	112
9 Jan. '11	1	Cellar	46·0	44·6	·92	44	37
27 Feb.	1	,,	52·3	50·8	·92	130	120
9 Jan.	1	Beehive	44·2	34·8	—	30	23
27 Feb.	1	,,	52·2	32·9	—	45	38
9 Jan.	1	Lab. Cupboard	52·4	43·0	·84	44	37
27 Feb.	1	,,	54·9	45·3	·85	31	24
9 Jan.	1	Incubator 75 Wet	74·5		·75	23	16
,,	1	,, 85 Wet	84·9		·68	21	14
,,	1	,, 75 Dry	76·5		·55	17	10
,,	1	,, 85 Dry	85·5		·56	12	5

TABLE LII. *Adult fleas.* C. fasciatus. *Length of life without further food after feeding on rats' blood for varying periods. A special cage was stocked on* 28 *Dec.* '10, *with fleas freshly emerged from cocoons kept in Incubator* 75 *Wet; these fleas were allowed opportunity of feeding upon a rat for* 24 *hours and upwards, afterwards being kept without food in filter paper tubes placed in sand pots.*

(*a*) *In Cellar.*

Date of commencement of test	No.	Allowed access to rat for	Temperature max.	Temperature min.	Humidity	Details	Longest period of survival unfed, days	Average period of survival unfed, days
29 Dec. '10	18	24 hours	46·5	45·3	·93	2 dead in 17 days	33	26
						4 ,, 21 ,,		
						8 ,, 27 ,,		
						1 ,, 30 ,,		
						3 ,, 33 ,,		
31 Dec. '10	15	48 ,,	46·5	45·3	·93	2 ,, 14 ,,	32	19
						2 ,, 19 ,,		
						3 ,, 25 ,,		
						2 ,, 28 ,,		
						4 ,, 31 ,,		
						2 ,, 32 ,,		
3 Jan. '11	10	72 ,,	46·5	45·3	·93	2 ,, 16 ,,	30	24
						2 ,, 22 ,,		
						2 ,, 25 ,,		
						2 ,, 28 ,,		
						1 ,, 29 ,,		
						1 ,, 30 ,,		
7 Jan. '11	11	1 week	46·5	45·3	·93	3 ,, 18 ,,	26	21
						5 ,, 21 ,,		
						2 ,, 25 ,,		
						1 ,, 26 ,,		

TABLE LII—*Continued.*

(*b*) *In Beehive.*

Date of commencement of test	No.	Allowed access to rat for	Temperature max.	Temperature min.	Humidity	Details	Longest period of survival unfed, days	Average period of survival unfed, days
9 Jan. '11	10	9 days	43·5	33·0	—	1 dead in 8 days	19	13
						4 ,, 11 ,,		
						4 ,, 15 ,,		
						1 ,, 19 ,,		

NOTE. Allowance must be made for the fact that the natural death rate might have already eliminated weaklings from the cage before the individuals were taken for the later experiments.

TABLE LIII. *Adult fleas.* Ct. canis. *Length of life without food. Fleas taken from the dog, put into Incubator* 75 *Wet at* 75° *F., Humidity* ·77 *for* 24 *hours* (*in order to obtain eggs for experiment*) *and then kept in filter paper tubes buried in sand pots in various situations.*

Date of commencement of test	No.	Place	Temperature max.	Temperature min.	Humidity	Detail	Longest period of survival unfed, days	Average period of survival unfed, days
8 Sept. '11	2	Cellar	63	62	·94	all dead in 4 days		
,,	2	Lab. Cupboard	73	61	·75	all ,, 2 ,,		
,,	2	Beehive	87	54·3	—	1 ,, 1 day	3	2
						1 ,, 3 days		
,,	2	Warm Cupboard	69·0		·66	all ,, 2 ,,	—	—
,,	2	Incubator 85 Wet	84·6		·81	1 ,, 1 day	3	2
						1 ,, 3 days		
,,	2	,, 75 Wet	75·0		·79	all ,, 1 day	—	—
,,	2	,, 75 Dry	75·5		·57	1 ,, 1 ,,	2	—
						1 ,, 2 days		
,,	2	,, 85 Dry	84·0		·62	all ,, 2 ,,	—	—

TABLE LIV. *Adult fleas.* P. irritans. *Length of life when fed on man.*

(*a*) *Freshly emerged fleas, kept in gauze-covered boxes in Laboratory or Bedroom and fed daily.*

Date of emergence	No.	Origin: Situation and food during larval stage	Origin: Days in cocoon	Length of life approximate*	Remarks
30 Mar. '11	1	Lab. Cupboard, blanket shakings	about 211	1 dead about 148 days	Commenced to lay 1 May '11
1 April	1	,, B.S. Rag	,, 160	1 ,, 160 ,,	
10 ,,	1	,, Flea faeces	,, 228	1 ,, 161 ,,	
18 ,,	1	,, B.S. Rag	,, 200	1 ,, 153 ,,	
21 ,,	1	,, ,,	,, 203	1 ,, 250 ,,	
22 ,,	1	,, ,,	,, 215	1 ,, 251 ,,	
27 ,,	1	,, ,,	,, 220	1 ,, 316 ,,	

* Those which were first to emerge are considered to be the first to die.

TABLE LIV—*Continued.*

(*b*) *Freshly emerged fleas, kept in gauze-covered boxes in Laboratory Cupboard and fed twice weekly.*

Date of emergence	No.	Temperature	max.	min.	Humidity	Length of life approximate
22 Dec. '10	2	Jan.	53·5	44·0	·84	1 dead in 75 days*
24 ,,	1	Feb.	52·8	43·6	·83	1 ,, 204 ,,
25 ,,	1	Mar.	55·2	45·5	·85	2 ,, 226 ,,
27 ,,	2	April	58·2	48·2	·78	1 ,, 231 ,,
		May	61·8	54·3	·78	1 ,, 239 ,,
		June	66·4	58·3	·79	
		July	71·5	62·7	·75	
		Aug.	72·0	64·1	·74	

(*c*) *Freshly emerged or captured fleas, kept in gauze-covered boxes in Laboratory or Bedroom and fed daily.*

Date of emergence or capture	No.	Origin	Length of life	Sex	Longest period of survival, days	Average period of survival, days
July '10	2	Captured	1 dead in 100 days	♀	162	130
			1 ,, 162 ,,	♀		
Aug. '10	4	Bred in Lab. Cupboard	1 ,, 131 ,,	♀	142	135
		freshly emerged	1 ,, 142 ,,	♀		
			1 ,, 135 ,,	♂		
			1 ,, 135 ,,	♂		
3 Oct. '10	1	Captured	1 ,, 58 ,,	♀	—	—
21 Feb. '11	18	Bred in Lab. Cupboard,	1 ,, 148 ,,	—	513	348
		freshly emerged (larvae	1 ,, 160 ,,			
		taken from dog's bed	2 ,, 177 ,,			
		Oct. '10)	1 ,, 190 ,,			
			1 ,, 360 ,,			
			2 ,, 377 ,,			
			2 ,, 388 ,,			
			1 ,, 397 ,,			
			1 ,, 424 ,,			
			2 ,, 434 ,,			
			1 ,, 437 ,,			
			2 ,, 443 ,,			
			1 ,, 513 ,,			

* This flea was found dead gummed to glass of the box by blood voided by the fleas; it is possible but not definite that this was the cause or contributory cause of death.

TABLE LIV (*c*).—*Continued.*

Date of emergence or capture	No.	Origin	Length of life	Sex	Longest period of survival, days	Average period of survival, days
3 June '11	10	Bred in Cellar, freshly emerged (larvae taken from dog's bed Oct. '10)	1 dead in 49 days	—	269	126
			1 ,, 72 ,,			
			2 ,, 80 ,,			
			2 ,, 84 ,,			
			1 ,, 100 ,,			
			1 ,, 192 ,,			
			1 ,, 258 ,,			
			1 ,, 269 ,,			
20 June '11	17	Bred in Incubator 75 Wet freshly emerged	1 ,, 58 ,,	—	252	112
			6 ,, 67 ,,			
			4 ,, 87 ,,			
			2 ,, 99 ,,			
			1 ,, 203 ,,			
			1 ,, 206 ,,			
			1 ,, 241 ,,			
			1 ,, 252 ,,			
		Fed twice a week.				
9 Mar. '11	7	Freshly emerged	4 ,, 92 ,,	—	166	121
			1 ,, 153 ,,			
			1 ,, 158 ,,			
			1 ,, 166 ,,			

(*d*) *Kept in the Cellar and fed daily until 2nd October and then once a week.*

Date of emergence or capture	No.	Origin	Length of life	Sex	Longest period of survival, days	Average period of survival, days
23 Aug. '11	11	Freshly emerged	1 ,, 103 ,,	—	511	281
			1 ,, 192 ,,			
			2 ,, 200 ,,			
			1 ,, 206 ,,			
			1 ,, 278 ,,			
			2 ,, 345 ,,			
			1 ,, 414 ,,			
			1 ,, 505 ,,			
			1 ,, 511 ,,			

TABLE LV. *Adult fleas. Length of life of various species when fed on rats. Fleas freshly emerged from cocoons in Incubator 75 Wet and kept in gauze-covered boxes in various situations.*

Species	Method of feeding	Date of emergence	Number	Place	Temperature max. min.	Humidity	Length of life	Aver.
C. fasciatus	Box method, 15 minutes daily	7 Oct. '10	5	Rat's cage	—	—	2 dead in 24 days 3 ,, 31 ,,	28 days
,,	,,	7 Feb. '11	10	Lab. Cupboard	56·7 47·7	·81	1 ,, 8 ,, 1 ,, 9 ,, 5 ,, 12 ,, 1 ,, 14 ,, 1 ,, 90 ,, 1 ,, 106 ,,	28 ,,
,,	Box method, 15 minutes every other day	12 Oct. '10	9	Incubator 85 Wet	83·9	·71	1 ,, 4 ,, 1 ,, 10 ,, 4 ,, 12 ,, 2 ,, 18 ,, 1 ,, 20 ,,	13 ,,
P. irritans	Box method, 15 minutes daily	4 Feb. '11	6	Lab. Cupboard	52·0 43·7	·84	1 ,, 3 ,, 1 ,, 6 ,, 1 ,, 8 ,, 1 ,, 9 ,, 1 ,, 11 ,, 1 ,, 14 ,,	8 ,,
,,	In cage with rat	30 Nov. '10	6	—	—	—	The last living specimen was seen 40 days from start	
Ct. canis	Box method, 15 minutes daily	17 Nov. '10	10	Lab. Cupboard	58·4 45·4	·85	1 dead in 24 days 1 ,, 30 ,, 3 ,, 34 ,, 1 ,, 46 ,, 1 ,, 48 ,, 2 ,, 54 ,, 1 ,, 58 ,,	41 days
,,	In cage with rat	27 Nov. '10	60	—	—	—	No record of individual deaths; they died off gradually, all were dead by 25 Dec. '10	

Table LVI. *Adult fleas,* C. fasciatus *and* X. cheopis. *Length of life when fed on man. Fleas freshly emerged from cocoons in Incubator 75 Wet, fed daily and kept in Laboratory Cupboard during the day and in Bedroom at night.*

Species	Date of emergence	Number	Length of life	Longest period of survival, days	Average period of survival, days
C. fasciatus	3 Oct. '10	6	1 dead in 17 days	79	39
			2 ,, 19 ,,		
			1 ,, 22 ,,		
			2 ,, 79 ,,		
,,	18 Oct. '10	4	1 ,, 4 ,,	76	35
			1 ,, 19 ,,		
			1 ,, 41 ,,		
			1 ,, 76 ,,		
,,	15 July '11	12	*10 ,, 13 ,,	62	18
			1 ,, 26 ,,		
			1 ,, 62 ,,		
X. cheopis.	15 July '11	19	3 ,, 18 ,,	100	38
			†12 ,, 33 ,,		
			1 ,, 55 ,,		
			1 ,, 65 ,,		
			1 ,, 67 ,,		
			1 ,, 100 ,, approximate		
,,	8 June '11	2	1 ,, 55 ,,	87	73
	13 ,,	4	2 ,, 66 ,,		
	11 July '11	9	4 ,, 69 ,,		
			1 ,, 70 ,,		
			3 ,, 71 ,,		
			4 ,, 87 ,,		

* 10 all died at one time, cause of death unexplained, possibly due to entanglement of legs in piece of cloth put into box to induce females to lay.

† All died on the same date. When removed from the box they were found to have their legs entangled in the cloth; whether this had any relation to their death or if it occurred subsequently to death is not known.

Species	Date of emergence or capture	Feeding	Origin	No.	Length of life	Longest period of survival, days	Average period of survival, days	Remarks
Ct. canis	30 Oct. '10	Box method, 15 minutes daily	Captured on Dog	3	1 dead in 38 days	62	51	—
					1 ,, 52 ,,			
					1 ,, 62 ,,			
,,	7 Nov. '10	,,	Bred (freshly emerged)	6	2 ,, 15 ,,	245	72	—
					1 ,, 31 ,,			
					1 ,, 45 ,,			
					1 ,, 84 ,,			
					1 ,, 245 ,,			
,,	17 May '11	,,	,,	8	2 ,, 66 ,,	345	145	—
					2 ,, 84 ,,			
					1 ,, 89 ,,			
					1 ,, 156 ,,			
					1 ,, 275 ,,			
					1 ,, 345 ,,			
Ct. felis	29 Dec. '10	,,	,,	5	1 ,, 139 ,,	185	156	—
					1 ,, 146 ,,			
					1 ,, 152 ,,			
					1 ,, 157 ,,			
					1 ,, 185 ,,			
C. gallinae	7 Nov. '10	,,	Captured on Dog	1	1 ,, 224 ,,	—	—	This specimen was a female, she laid a few infertile eggs during the spring of 1911
,,	12 Feb. '10		Captured in nest of Blue Tit (apparently freshly emerged)	7	1 ,, 6 ,,	41	18	These fleas were observed to copulate before feeding commenced. *One female laid fertile eggs after some weeks captivity. 11 fleas were reared from these eggs
					1 ,, 8 ,,			
					2 ,, 15 ,,			
					1 ,, 22 ,,			
					1 ,, 25 ,,			
					*1 ,, 41 ,,			
L. musculi	31 May '12	15 to 20 minutes daily	Bred in Incubator 75 Wet, larvae taken from cages (freshly emerged)	11	5 ,, 4 ,,	10	6	One noted very full of blood
					2 ,, 5 ,,			
					3 ,, 8 ,,			
					1 ,, 10 ,,			
,,	19 April '12	,,	,, ,,	6	2 ,, 3 ,,	5	4	,, ,,
					3 ,, 4 ,,			
					1 ,, 5 ,,			
Spilopsyllus cuniculi	12 April '12	,,	Reared from a rabbits' nest	19	9 ,, 13 ,,	69	27	Kept under living room conditions when not feeding
					3 ,, 24 ,,			
					4 ,, 38 ,,			
					1 ,, 52 ,,			
					1 ,, 56 ,,			
					1 ,, 69 ,,			

TABLE LVIII. *Adult fleas.* Ct. canis *and* C. fasciatus. *Length of life without food when kept in various situations and supplied with a small piece of blotting paper moistened with distilled water each night.*

Species	Date of emergence or capture	Origin	No.	Place kept during test	Temperature max.	Temperature min.	Humidity	Detail	Longest period of survival, days	Average period of survival, days
C. fasciatus	18 Nov. '10	Bred, freshly emerged	4	Lab. Cupboard	55·0	45·6	·85	1 dead in 9 days 1 ,, 12 ,, 1 ,, 39 ,, 1 ,, 48 ,,	48	27
,,	4 ,,	Captured	4	,,	54·0	42·8	·84	1 ,, 21 ,, 2 ,, 24 ,, 1 ,, 26 ,,	26	23
Ct. canis	17 ,,	Bred, freshly emerged	10	Incubator 85 Wet	Dry	83·9	·71	1 ,, 4 ,, 5 ,, 8 ,, 4 ,, 10 ,,	10	8
,,	17 ,,	,,	10	,, 75 Wet		74·3	·73	1 ,, 4 ,, 3 ,, 10 ,, 1 ,, 12 ,, 1 ,, 15 ,, (Remainder escaped)	15	10
,,	17 ,,	,,	9	Warm Cupboard		59·5	·57	1 ,, 11 ,, 2 ,, 14 ,, 3 ,, 17 ,, 1 ,, 18 ,, 1 ,, 20 ,, 1 ,, 21 ,,	21	17
,,	17 ,,	,,	8	Lab. Cupboard	55·3	46·2	·85	1 ,, 11 ,, 2 ,, 15 ,, 1 ,, 18 ,, 2 ,, 22 ,, 1 ,, 27 ,, 1 ,, 34 ,,	34	20
,,	17 Feb. '11	,,	13	Incubator 75 Dry		75·6	·51	1 ,, 3 ,, 6 ,, 4 ,, 2 ,, 5 ,, 1 ,, 7 ,, 1 ,, 9 ,, 2 ,, 10 ,,	10	6
,,	21 ,,	,,	10	,, 85 Dry		83·9	·59	4 ,, 3 ,, 4 ,, 6 ,, 1 ,, 9 ,, 1 ,, 10 ,,	10	5

TABLE LIX. *Adult fleas.* Ct. canis *and* C. fasciatus. *Length of life of freshly emerged specimens, when supplied with various artificial foods. Liquid food supplied on pad of blotting paper or greasy sheeps' wool put into their boxes and remoistened each night.*

Species	Nature of liquid supplied	Date of emergence	No.	Place kept during test	Temperature max.	Temperature min.	Humidity	Length of life	Longest period of survival, days	Average period of survival, days
Ct. canis	(*A*) Broth on blotting paper	17 Aug. '11	10	Lab. Cupboard	70·5	61·8	·76	5 dead in 4 days	22	8
								1 ,, 5 ,,		
								1 ,, 7 ,,		
								1 ,, 12 ,,		
								1 ,, 18 ,,		
								1 ,, 22 ,,		
,,	(*B*) Water on blotting paper	15 Aug.	14	,,	70·3	61·8	·75	1 ,, 6 ,,	26	13
								2 ,, 7 ,,		
								3 ,, 9 ,,		
								1 ,, 12 ,,		
								1 ,, 15 ,,		
								3 ,, 16 ,,		
								1 ,, 18 ,,		
								1 ,, 20 ,,		
								1 ,, 26 ,,		
C. fasciatus	(*A*) Broth with sugar on blotting paper	26 May	10	,,	68·8	61·4	·76	1 ,, 4 ,,	8	6
								3 ,, 5 ,,		
								1 ,, 6 ,,		
								5 ,, 8 ,,		
,,	(*B*) Water on blotting paper	26 May	10	,,	66·6	58·9	·79	1 ,, 12 ,,	42	22
								1 ,, 14 ,,		
								1 ,, 16 ,,		
								1 ,, 17 ,,		
								1 ,, 22 ,,		
								2 ,, 23 ,,		
								1 ,, 29 ,,		
								1 ,, 42 ,,		
								1 escaped		

TABLE LIX.—*Continued.*

Species	Nature of liquid supplied	Date of emergence	No.	Place kept during test	Temperature max.	Temperature min.	Humidity	Length of life	Longest period of survival, days	Average period of survival, days
C. fasciatus	(*A*) Broth with sugar on blotting paper	29 June	12	Lab. Cupboard	68·1	60·1	·80	6 dead in 8 days 5 ,, 10 ,, 1 ,, 12 ,,	12	9
,,	(*A*) Broth with sugar on pad of wool	29 May	8	Incubator 75 Wet	74·2		·91	1 ,, 1 day 7 ,, 2 days	2	2
,,	(*B*) Water on pad of wool	30 May	10	,,	75·9		·80	1 ,, 1 day 2 ,, 3 days 1 ,, 4 ,, 5 ,, 6 ,, 1 escaped	6	4
,,	(*A*) Broth with sugar on pad of wool	1 June	11	Cellar	59·2	57·7	·93	1 dead in 2 ,, 2 ,, 4 ,, 3 ,, 5 ,, 2 ,, 7 ,, 3 ,, 13 ,,	13	7
,,	(*B*) Water on pad of wool	2 June	10	,,	58·8	57·2	·93	2 ,, 6 ,, 6 ,, 12 ,, 2 ,, 13 ,,	13	11
,,	(*A*) Broth on blotting paper	10 July	9	Lab. Cupboard	70·6	60·8	·74	1 ,, 3 ,, 7 ,, 5 ,, 1 ,, 6 ,,	6	5
,,	(*B*) Water on blotting paper	10 July	7	,,	72·9	63·7	·73	1 ,, 11 ,, 2 ,, 16 ,, 2 ,, 21 ,, 2 escaped	21	17
,,	(*B*) ,, ,, ,,	15 Aug.	35	Incubator 75 Dry	74·7		·59	2 dead in 4 ,, 3 ,, 6 ,, 8 ,, 7 ,, 7 ,, 8 ,, 6 ,, 9 ,, 2 ,, 10 ,, 5 ,, 11 ,, 1 ,, 13 ,, 1 ,, 15	15	8

v. *Possibility of continued breeding in the absence of any host.*

Some experiments were made in order to see whether fleas could establish themselves in the absence of a host, by throwing successive broods, the necessary nutriment for reproduction by the adults being obtained, as in case of so many insects, by the surplus passed on from the larval period. Many of the experiments with adults, although performed for other purposes, afford evidence bearing on this subject, but the procedure was arranged in these special tests with a view to making the attendant circumstances as favourable as possible. The evidence obtained is entirely negative in character.

P. irritans. A large glass jar was stocked with a quantity of carpet sweepings and greasy unwashed sheep's wool. · Some 270 newly hatched larvae were added and the jar was placed in the cellar on the 22nd May, 1911. Periodic examinations were made from 23rd September, 1911, onwards to September, 1912. A few adult fleas were seen during September and October, 1911, but none afterwards and no trace of larvae could be found.

C. fasciatus. A similar glass jar, stocked in the same way, was placed in the cellar on the 30th May, 1911, and 110 newly hatched larvae of *C. fasciatus* were added. A number of adult fleas (36 in all) were found from time to time up to the 10th May, 1912. Subsequent examinations up to September, 1912, were barren and no trace of any larvae could be found.

C. gallinae. Material taken from a nesting box used by a blue tit was received in June, 1911. It was kept in a glass jar in the beehive. Neither larvae nor fleas could be found when it was taken from the box. An examination in September, 1911, showed that some *C. gallinae* had emerged; cocoons were also discovered and opened and found to contain living fleas. Fleas continued to emerge up to the 24th April, 1912, but no larvae could be detected at any time up to September, 1912. Another blue tit's nest, received on the 9th October, 1911, and kept in the beehive, gave a similar record—the last living flea being found on the 7th March, 1912, but no larvae could be discovered.

A further experiment was made with *P. irritans* starting with freshly emerged adults. A large glass jar was prepared with a quantity of carpet sweepings and greasy unwashed sheep's wool and placed in the cellar on 22nd May, 1911. 20 freshly emerged *P. irritans* were fed for one week, then kept in a box in the cellar for a further week, to see if any ova would be laid immediately after the feeding. No ova were laid and the fleas were then put into the jar mentioned above.

Examinations were made periodically from September, 1911, to May, 1912, but no signs of either larvae or fleas could be found.

The cellar was chosen for the above experiments as, in consequence of the long survival period of living fleas kept there, it was thought to afford the most favourable situation for continued breeding. In order to test the possibility of egg laying under conditions exactly similar to those used to obtain eggs from fed captives, the following experiment was performed with unfed adult fleas.

A number of freshly emerged males and females of *P. irritans*, *X. cheopis* and *C. fasciatus* were placed in boxes having the cloth ring (as described in the general chapter on Methods, p. 464) and put away as follows:

Warm Cupboard. The boxes containing the fleas were kept in a moist chamber (temperature about 64° F. and the air kept as near saturation as possible).

Date	No.	Species	Remarks
15 Aug. '12	30	*P. irritans*	by the 31 Aug. all had died, no eggs were laid
,,	30	*X. cheopis*	,, ,, ,, ,,
,,	30	*C. fasciatus*	,, ,, ,, ,,

Incubator 75 Wet. Boxes containing the fleas were buried in a mass of carpet sweepings (fluff and dust) (temperature about 74° F., humidity about ·81).

15 Aug. '12	15	*P. irritans*	by the 30 Aug. all had died, no eggs were laid
,,	30	*X. cheopis*	,, ,, ,, ,,
,,	30	*C. fasciatus*	,, ,, ,, ,,

Incubator 75 Wet. Boxes containing the fleas were buried in sand (temperature about 75° F., humidity ·75 to ·80).

18 Sept. '12	30	*C. fasciatus*	by the 5 Oct. '12 all were dead, no eggs were laid
,,	30	*X. cheopis*	,, 28 Sept. '12 all had died, ,, ,,

In further support of this negative result it may be noted that when flea breeding cages are kept for more than two or three months without a host for the fleas to feed on, adults will still be found present but no larvae. Cages used for breeding *C. fasciatus* were found to contain imagines 10 months after the removal of the rat but no active larvae were ever discovered.

This question is discussed at greater length in the general chapter dealing with the bionomics of fleas, Section IV, pp. 477—480.

vi. *Fertility of males and survival of spermatozoa in the spermathecae of the female.* P. irritans.

My interest in Rösel von Rosenhoff's (1749) statement that fleas only copulate three times—the males not being able to fertilize after the third occasion—led me to make the following observations on captive specimens of *P. irritans*.

A single male of *P. irritans* was kept with four or five females for over a month, and though eggs were removed every three or four days there was no occasion on which all the eggs were infertile.

Two females were kept in a box with a male; the male was then taken away on the 24th July, 1910, and the females transferred to a fresh box. The change to a fresh box was repeated at intervals.

Eggs laid	28th	July	to	1st	August—	none	hatched
,,	2nd	August	,,	5th	,,	,,	,,
,,	6th	,,	,,	11th	,,	,,	,,
,,	12th	,,	,,	14th	,,	,,	,,

Later a male was then added to the above mentioned two females with the following results :—

26th September 1910 : 6 eggs laid, but did not hatch.
1st October 1910 : 12 eggs laid from which 11 larvae hatched.

A further trial was made as follows :—

6th	October 1910:	The same two females and a male—10 eggs laid, at least two larvae hatched.				
15th	,,	as above—	12	eggs laid,	7 larvae	hatched.
22nd	,,	,,	7	,,	1 larva	,,
25th	,,	,,	5	,,	none	,,
1st	November, 1910:	,,	6	,,	none	,,
8th	,,	,,	4	,,	2 larvae	,,

Twelve eggs were laid by a captured female some five days to a week after capture—one egg hatched.

A week or 10 days later this female laid 6 more eggs, having had no intercourse with a male—none of the eggs hatched.

Seven eggs which were laid by a virgin female kept and fed in a separate box did not hatch.

The suggestion to be gleaned from these observations was that, as a single male fertilized the eggs of at least one of a number of females for more than a month, Rösel von Rosenhoff's statement, alluded to above, must be incorrect, and further that females could not continue to lay fertile eggs after separation from the male for a few days.

The following experiment, however, made in the autumn of 1911, shows that the last conclusion was incorrect, and that females may retain the power of laying fertile eggs for a considerable period after copulation.

A number of freshly emerged females and males were put into a box and fed for 12 days, when all the males were removed and the females' oviposition recorded. The latter were kept at 75° F. when not feeding.

Date	Number of ova laid	Number hatche
19th October 1911	18	Nil
21st ,,	10	2
25th ,,	42	19
28th ,,	38	7
2nd November 1911	44	15
6th ,,	40	1
10th ,,	8	Nil
14th ,,	10	1
18th ,,	16	Nil
24th ,,	11	Nil
28th ,,	8	Nil
2nd December 1911	9	3
9th ,,	7	1
14th ,,	11	Nil
19th ,,	10	Nil

The following two series of experiments were then put in hand with a view to settling the questions raised by the earlier trials, the object being to test the fertilizing power of a male and to determine the length of time during which the female retains the power of laying fertile eggs without access to a second male.

The method employed was the following: a single male was selected out of a number of freshly emerged fleas and allowed to remain at least four days in succession with each of a number of females freshly emerged from cocoons that had been kept in separate tubes to avoid any possibility of random pairing.

The ova were removed from the boxes every three or four days. All the specimens when not feeding were kept in Incubator 75 Wet.

Fertility experiment with P. irritans. SERIES I.

The male used emerged from cocoon on 3 Feb. 1912.

Female	Date of emergence from cocoon	Male added	Male removed	Started to lay	No. of eggs laid	Number hatched	Remarks
No. 1	3 Feb. '12	5 Feb. '12	12 Feb. '12	4 Mar. '12	2 2	0 0	
,, 2	3 ,,	12 ,,	16 ,,	26 Feb. '12	1 1 1	0 0 0	
,, 3	3 ,,	16 ,,	20 ,,	24 ,,	2 2	0 0	
,, 4	3 ,,	20 ,,	24 ,,	—	—	—	did not lay
,, 5	3 ,,	24 ,,	28 ,,	8 Mar. '12	2 7	0 0	
,, 6	3 ,,	28 ,,	3 Mar. '12	5 ,,	6 3 1	0 0 0	
,, 7	16 ,,	3 Mar. '12	7 ,,	8 ,,	4 5	0 0	
,, 8	19 ,,	7 ,,	11 ,,	16 ,,	3	0	
,, 9	20 ,,	11 ,,	15 ,,	16 ,,	6	3	
,, 10	29 ,,	15 ,,	19 ,,	—	—	—	did not lay

SERIES NO. I. In the experiments of the first series (see Table above), none of the eggs laid by the first eight females hatched. It was therefore decided to abandon the experiment, on the ground that the male was in some way defective. This decision had already been acted on and the females added to the general stock before the ova laid by female No. 9 had hatched.

SERIES NO. II. The second series was successfully carried through. The results are of considerable interest, and show the large amount of variation that exists both in regard to the egg laying capacity of the females of *P. irritans* and the fertilizing powers of the males. While the conditions of the experiment were not exactly natural they were not unfavourable, and are likely to differ from what obtains under free conditions only as regards the restriction of the opportunities for copulation. As a measure of variation between one specimen and another the results of the experiments seem perfectly valid.

The result to be gleaned from Series II (*a*), April to June 1912 (see Table on pp. 639, 640), is that a single male is able to fertilize as many as 13 females, but that the supply of sperms passed to the female becomes exhausted within a period of from one to two months. In order to make sure that the failure of the eggs to hatch was due to the absence of a male and not to some defect in the females, a second male was placed with females Nos. 1, 2, 3, 9, 13 and 14 after they had each laid at least six batches of infertile eggs, that is after a period of about 25 to 30 days had elapsed since any fertile ova had been laid.

The sequel Series II (*b*) to Series II (*a*) lasted from June to December 1912, and the results entirely confirm those previously obtained. The course of the experiment was interrupted by a change in the food from the middle of July to the end of August 1912, when the insects were fed by my assistant during my absence from home. It will be noted that egg laying fell off at about this period, possibly owing to the change of diet, but more probably either because they did not get such full meals, or because there was a considerable fall in mean temperature during the latter half of July and throughout August, 1912. Upon my return I decided to keep the insects in incubator 75 Wet in order to finish the fertility observations, and I also instituted a separate experiment to test the effect of differential feeding.

Towards the close of the experiment the daily periods allowed for feeding were considerably increased and the eggs were allowed to accumulate for periods of 5, 6 or even 7 days before removal; it is to these causes that the apparent spurt in egg laying (see for example, females Nos. 13 and 14 in Series II (*b*)) is to be, at any rate in part, attributed, but the number of collapsed and small sized eggs suggested also some failure of control in oviposition. This may have been due either to old age or perhaps to the unnatural condition of long continued warmth and high feeding in place of the normal state of rest or partial hibernation that occurs with this species during the winter.

The introduction of a third male in the case of females Nos. 1, 9, 13 and 14 after the lapse of the period of fertility due to the second copulation, resulted again in the production of fertile eggs by females Nos. 1, 13 and 14. It seems reasonable to suppose that the failure in the case of No. 9 was due to some defect in coitus rather than to failing powers on the part of the female to produce ova capable of fertilization. That the fault lay with the female rather than with the male seems definite as the later introduction of a fourth male did not alter the state of affairs.

It will be seen that female No. 13 was by far the most productive of those tested; she laid 448 eggs, of which 115 were fertile, in a total period of 196 days. This specimen is also to be credited with the ability to retain the power of fertilizing her eggs for the longest period, 65 days.

Fertility experiment with P. irritans. SERIES II (*a*).

The first male used emerged 1 April 1912.

Female	Date of emergence from cocoon 1912	Male added 1912	Male removed 1912	Started to lay 1912	Number of eggs laid, 4 day totals	Number of eggs which hatched, 4 day totals	Effective period of fertilization	Total number of eggs	Number of eggs fertilized	Percentage of fertile ova laid, calculated for period of fertility only	Remarks
No. 1	1 April	5 April	9 April	12 April	6 9 9 11 8 6 4 3 3 5 2 8 5 3 5	4 6 4 5 5 2 0 0 0 0 0 0 0 0 0	24 days	87 in 62 days	26	53 %	—
,, 2	3 ,,	9 ,,	13 ,,	13 ,,	6 6 4 6 8 7 8 8 6 2 2 2 0 0 4 4	3 5 2 3 5 4 4 3 3 2 0 0 0 0 0 0	40 ,,	73 ,, 70 ,,	34	55	—
,, 3	9 ,,	13 ,,	17 ,,	18 ,,	1 4 7 3 5 9 6 3 3 4 0 4 6 3 3	0 3 2 1 0 1 1 2 0 0 0 0 0 0 0	32 ,,	61 ,, 69 ,,	10	26	Copulation observed
,, 4*	16 ,,	17 ,,	21 ,,	23 ,,	5 7 10 6 10 6 5	3 6 5 3 4 4 1	—	49 ,, 28 ,,	26	53	—
,, 5*	16 ,,	21 ,,	25 ,,	30 ,,	3 3 3 2 3	1 1 2 0 2	—	14 ,, 20 ,,	6	42	—
,, 6*	16 ,,	25 ,,	29 ,,	28 ,,	7 11 10 11 14	4 3 7 5 4	—	53 ,, 20 ,,	23	42	Copulation observed
,, 7*	22 ,,	29 ,,	3 May	1 May	4 7 7 7 3	1 6 4 4 2	—	28 ,, 20 ,,	17	60	—
,, 8*	25 ,,	3 May	7 ,,	5 ,,	6 7 6 6	3 3 3 3	—	25 ,, 16 ,,	12	48	—
,, 9	25 ,,	7 ,,	11 ,,	11 ,,	8 8 11 7 5 6 4 7 5 4 3 0 3 0 6 3 6 0 0 0	4 4 10 5 4 2 3 0 3 3 1 0 0 0 0 0 0 0 0 0	44 days	86 ,, 81 ,,	39	57	Copulation observed
,, 10†	2 May	11 ,,	15 ,,	16 ,,	3 3 3 4 4 4 6	3 1 1 3 3 2 3	—	27 ,, 28 ,,	16	58	—
,, 11†	14 ,,	15 ,,	19 ,,	22 ,,	4 7 7 7 3	0 2 5 3 2	—	28 ,, 20 ,,	12	42	Copulation observed
,, 12	19 ,,	24 ,,	28 ,,	8 June	4 4 8 5 6 4 5 6	0 0 0 0 0 0 0 0	—	42 ,, 32 ,,	none	—	Flea removed from experiment
,, 13	28 ,,	28 ,,	1 June	6 ,,	11 9 6 7 14 8 10 5 5 10 5 3 6 1 0 2 0 0	5 5 4 6 6 4 5 3 1 0 0 0 0 0 0 0 0 0	36 days	93 ,, 86 ,,	39	51	—
,, 14	1 June	1 June	6 ,,	10 ,,	9 5 4 11 7 0 5 1 6 6 0 4 0 0 3 0 0	0 3 2 7 3 0 2 0 1 0 0 0 0 0 0 0 0	36 ,,	61 ,, 93 ,,	18	37	—
,, 15	6 ,,	6 ,,	12 ,,	12 ,,	2 0 3 7 0 5	0 0 0 0 0 0	—	17 ,, 24 ,,	none	—	Male died 12 June '12 while in box with No. 15. Flea removed from experiment

* Numbers 4 to 8 removed from the experiment on 20 May '12 in order to make room for fresh females. † Numbers 10 and 11 also removed.

NOTE. Owing to the time involved and the difficulties in feeding when so large a number of separate boxes were required it was found necessary to limit the experiment. Nos. 4, 5, 6, 8, 10, and 11 were therefore removed on the 20th May (as events happened rather unnecessarily, as the male brought the series to a close by dying on the 12th June).

Fertility experiment with P. irritans. SERIES II (*b*).

Second male, emerged 13 June '12, died after having been placed with females Nos. 1, 2 and 3. Another male, emerged 1 Aug. '12, was used for Nos. 9, 13 and 14.

Female	Male added 1912	Male removed 1912	Number of eggs laid, 4 day totals	Number of eggs which hatched, 4 day totals	Effective period of fertilization	Total number of eggs	Number of eggs fertilized	Percentage of fertile ova laid, calculated for period of fertility only	Remarks
No. 1	13 June	22 June	7 10 12 9 10 7 7 15 5 3 0 0 0 0 0 0 0 0 *2 4 4 4	1 3 5 5 8 1 7 11 0 1 0 0 0 0 0 0 0 0 0 0 0 0	40 days	99 in 88 days	42	49 %	—
,, 2	22 ,,	26 ,,	0 1 3	0 0 0	Nil	4 ,, 25 ,,	Nil	—	Died 17 July '12
,, 3	26 ,,	1 July	11 9 10 8 10 3 5 4 1	4 4 4 0 0 0 0 0 0	16 days	61 ,, 57 ,,	12	40	,, 22 Aug. '12
,, 9	1 Aug.	1 Sept.	2 0 3 0 0 3 *9 0 6 3 3 2 2 1	0 0 0 0 0 0 4 0 0 0 0 0 0 0	doubtful	34 ,, 56 ,,	4	doubtful	—
,, 13	1 Sept.	11 ,,	*8 11 12 10 8 10 7 6 4 5 0 8 0 7 9 8 0 6 18 28 26 56 32	4 9 10 10 6 9 5 5 2 1 0 2 0 0 1 2 0 0 0 0 0 0 0	about 65 days	279 ,, 90 ,,	75	58	—
,, 14	11 ,,	16 ,,	*3 12 7 7 9 2 4 2 2 0 3 0 0 0 2 0 5	2 3 2 2 3 2 0 0 1 0 1 0 0 0 0 0 0	—	—	—	—	—
				Third Male, freshly emerged.					
,, 1	21 ,,	2 Oct.	7 10 5 10 7 10 4 4 3	6 6 3 8 4 7 2 0 0	,, 30 ,,	60 ,, 36 ,,	36	60	Died 28 Oct. '12
,, 9	10 Oct.	20 ,,	2 2 0 1 5 0 4 5 0 5 11 17 13 6 6 3 2	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Nil	82 ,, 70 ,,	Nil	—	,, 2 Feb. '13. A fourth male tried but no eggs were laid
,, 13	29 Nov.	18 Dec.	27 10 27 12	0 0 1 0	doubtful	76 ,, 20 ,,	1	1	Died 2 Feb. '13
,, 14	29 ,,	18 ,,	19 30 7 14	1 5 0 0	8 or 10 days	70 ,, 16 ,,	6	8	,, 27 Dec. '12

* This mark is placed against a batch of eggs to signify that from this time onwards the females were kept in an incubator at 70° F. It was necessary to pursue this course as the cold weather had caused a cessation of egg laying.

vii. *Influence of food supply upon the number and fertility of eggs.*

P. irritans.

The following experiment was specially arranged to investigate the influence of the amount of food provided for the adult upon the number and fertility of the eggs laid. The results do not exhibit any clear connection between the opportunities afforded for feeding and the percentage of eggs hatching, but, on the other hand, show very definitely the extent to which the total number of eggs laid is dependent on food supply.

Experiment with P. irritans. *The influence of food supply upon (a) the number of eggs laid and (b) their fertility.*

Method. A number of freshly emerged fleas were fed for a few days. 5 males and 5 females were selected and then put into each of two boxes. The specimens in Box No. 1 were fed once a day, those in Box No. 2 twice a day.

Box No. 1			Box No. 2		
No. of eggs laid, 3/4 day totals	No. of eggs hatching, 3/4 day totals	% hatching	No. of eggs laid, 3/4 day totals	No. of eggs hatching, 3/4 day totals	% hatching
23 36 49 16 44	12 25 30 11 38		23 62 98 39 55	11 32 66 31 36	
Total 168	Total 116	69 %	Total 277	Total 176	63 %

A female in Box No. 2 died and one was taken out of Box No. 1 for the sake of uniformity.

The feeding was reversed after the 5th batch of eggs had been removed. The individuals in Box No. 1 were fed twice a day and those in Box No. 2 once per day.

50 62 44 76 57	34 45 34 54 42		50 44 30 47 24	31 27 26 41 21	
Total 289	Total 209	71 %	Total 195	Total 146	75 %

SECTION VI. INFLUENCE OF LOW TEMPERATURE UPON THE VARIOUS STAGES.

Ice Chest Experiments (Table LX). *X. cheopis* bred too slowly in the cages during the cool months of the year to afford a plentiful supply of the insect in all its stages. In consequence experiments with this species were practically restricted to the summer and autumn months and, in order to investigate in detail the influence of low temperature upon the various stages in its life history, recourse was had to a small ice chest kept in the cellar. It was thought well to try *P. irritans* and *C. fasciatus* at the same time for purposes of comparison. The humidity was high—bordering on saturation—and the temperature fairly constant at about 40° F., save on a few occasions when the local supply of ice failed. In this case the extreme range was between 35° F. and 45° F., mounting for a few hours a day to 50° F. and on one occasion to 54° F.

The results afford further evidence of greater susceptibility to low temperatures on the part of *X. cheopis* than in the case of *P. irritans* and *C. fasciatus* that was apparent in the breeding experiments and also carried out during the autumn of 1911 (Table XXV, p. 532). In all stages, save the imaginal, low temperatures below 45° F. were fatal to *X. cheopis.* As a means of destroying brood, cold air might be used as successfully as any of the usual insecticides against this species, and no further explanation is required for its failure to establish itself in cool or cold climates.

These experiments also bring out clearly the difference between *P. irritans* and *C. fasciatus* in their ability to breed under cool conditions. The record of all three species is the more interesting if the results of this experiment are compared with those obtained previously under the moderate temperatures (47—55° F.) afforded in the cellar.

Egg stage (Table LX (*a*)). While *C. fasciatus* can hatch at an average temperature of 41° F., *P. irritans* cannot, but a rise of 8 or 9° F. allows a percentage to hatch (see Table VI). To induce ova of *X. cheopis* to hatch a temperature of over 60° F. is apparently necessary (see Table VII, p. 497).

Larval stage (Table LX (*b*)). Here again it will be noted that, while *X. cheopis* and *P. irritans* cannot survive below 40° F., *C. fasciatus* is not only able to endure but apparently finds this temperature quite suited to its needs. The only factor that prevented all the larvae being reared to cocoon stage was the length of time taken by lagging larvae.

Cocoon stage. At 40—43° F. the results were similar to those obtained with the larvae. The greater endurance of *P. irritans* than *X. cheopis* appears from the fact that five of the former reached the pupal or imaginal stage before death, but only one of the latter survived the larval period.

Adult stage. The disparity here is not nearly so marked, *X. cheopis* being nearly or quite as hardy as *P. irritans,* while all three species are more nearly alike in this stage than in any previous one.

TABLE LX. *Ice chest experiment. Relative endurance at low temperature of* X. cheopis, P. irritans *and* C. fasciatus *at various stages in their life history.*

General record of Temperature and Humidity during the experiment.

Month	Temperature Highest	Temperature Lowest		Temperature Average	Humidity
April '12	49	35	(Average of 31 readings)	39·3	·92
May	54	35	(,, 53 ,,)	39·3	·95
June	50	35	(,, 50 ,,)	40·9	·99
July	60	37	(,, 43 ,,)	43·6	·95

(*a*) Eggs, laid in Incubator 75 Wet.

Date	Species	Number	Temperature Extremes	Temperature Aver.	Humidity	Number hatched	Mortality
7 June '12	*X. cheopis*	10	50° 35°	40·9	·99	Nil	100 %
,,	*P. irritans*	10	50° 35°	40·9	·99	Nil	100
,,	*C. fasciatus*	10	50° 35°	40·9	·99	5	50

(*b*) Larvae, newly hatched in Incubator 75 Wet, unfed, placed in small glass tubes containing a little sand and plugged with cotton wool.

Date	Species	Number	Temperature Extremes	Temperature Aver.	Humidity	Length of life, days Minimum	Length of life, days Maximum	Average length of life
29 April '12	*X. cheopis*	6	40° 36°	38·2	·97	2	3	2 days
,,	*P. irritans*	9	49° 35°	37·0	·95	2	46	13 ,,
,,	*C. fasciatus*	8	54° 35°	39·0	·96	9	52	43 ,,

Active (feeding) larvae of various sizes taken from the cages (or in the case of *P. irritans* from stock pot in Incubator 75 Wet) and placed in card jars with sand and blood-soaked rag.

Date	Species	Number	Temperature Extremes	Temperature Aver.	Humidity	Number of cocoons found	Number of fleas reared	Interval during which larva were observed	Mortality
15 April '12	*X. cheopis*	32	46° 37°	40	·94	none	none	No larvae seen alive after 3 days	100 %
,,	*P. irritans*	22	49° 37°	41	·93	,,	,,	, ,, ,, 8 ,,	100
,,	*C. fasciatus*	22	49° 35°	April 39·3	·92	16*	—	,, ,, ,, 56 ,,	No mortality during the course of experiment
			54° 35°	May 39·3	·95				
			50° 35°	June 40·9	·99				
			60° 37°	July 43·6	·95				

* 16 Aug., 1 flea emerged; 6 Sept., 2 cocoons opened contained resting larvae; 9 Sept., 13 cocoons opened contained resting larvae.

TABLE LX.—*Continued.*

(*c*) Cocoons, spun by larvae in Incubator 75 Wet.

Date	Species	Number	Temperature		Humidity	Number of fleas which emerged	Aver. number of days in cocoon	Remainder of cocoons opened and found to contain
			Extremes	Aver.				
15 April '12	*X. cheopis*	23	April 49° 35°	39·3	·92	mortality at least 96 %	—	Two larvae came out of cocoons and died within the first few days. Remaining cocoons opened 26 July contained 20 dried up larvae and 1 living pupa (transferred to Incubator 75 Wet, since died)
			May 54° 35°	39·3	·95			
			June 50° 35°	40·9	·99			
			July 60° 37°	43·6	·95			
,,	*P. irritans*	18				mortality 100 %	—	Three larvae came out of their cocoons, two died, one pupated. Remaining cocoons opened 26 July contained 2 dried up fleas, 2 dried up pupae, 11 dried up larvae
,,	*C. fasciatus*	22				15 emerged up to 26 July mortality, nil	91	Remaining cocoons transferred to cellar 26 July

Remaining cocoons opened 9 Sept. contained 5 resting larvae, 2 empty ("false" cocoons).

(*d*) Adult fleas, newly emerged and unfed, kept in card jars with sand at bottom to burrow in.

Date	Species	Number	Temperature		Humidity	Length of life, days		Average length of life, days
			Extremes	Aver.		Minimum	Maximum	
29 April '12	*X. cheopis*	11	54° 35°	39·3	·95	7	36	20
,,	*P. irritans*	4		39·3	·95	7	38	16
,,	*C. fasciatus*	11		39·8	·96	7	51	34

SUMMARY.

Eggs and egg-laying.

In comparison with the later stages in life history eggs are relatively insusceptible to external conditions. The range of variability in the length of time between laying and hatching, 2 to 10 days, is a small one and there is no appreciable tendency to utilize this stage for resting, the response to temperature changes being simple and direct.

The upper limit of temperature which is fatal to eggs has not been determined. *C. fasciatus* showed a high percentage hatching at 85° F. (see Table IV), while in the case of *P. irritans* 9 °/₀ hatched at 93° F. (see Table VI *a*), and on one occasion (Table VIII, series III) 27 °/₀ of the eggs of *X. cheopis* hatched at 93° F. At low temperatures the numbers which hatch in the case of all three species is reduced and cold is fatal to eggs of *P. irritans* and *X. cheopis*. In the ice chest, at an average temperature of 40·9° F. (see Table LX), 50 °/₀ of the eggs of *C. fasciatus* hatched, while all those of *X. cheopis* and *P. irritans* failed. A small proportion of eggs of the latter species hatched at 46° F., but in the neighbourhood of 55° F. appears to be the minimum for *X. cheopis*.

As regards the influence of humidity upon the hatching of eggs, in the range used in these experiments, only the larger differences produced consistent results, and, although there were some complete failures of hatching under conditions of low humidity, the evidence does not seem clear enough to warrant these being considered conclusive tests. On the whole, it is safe to say that a temperature of 65° to 80° F. with a humidity of ·70 or over is most favourable and that if the temperature be above 60° F. humidities below ·50 to ·55 are harmful. In the case of *P. irritans* there is possibility of complete failure at a humidity of ·50 but 70 °/₀ of the eggs of *C. fasciatus* hatched at a temperature of 75° F. with a humidity of only ·48 (see Tables II and IV).

Females of *C. fasciatus* show, in some cases, a fall in egg production under conditions of drought, but the effect is not noticeable with *P. irritans* and *X. cheopis*. Low temperatures check or prevent oviposition.

In the case of *C. fasciatus* and *P. irritans* warmth (75° F.) combined with low humidity, favours the fertility of eggs laid. This, in the case of *C. fasciatus*, might possibly be explained on the assumption that the fertility of ova is likely to be in inverse ratio to the number laid (see Table IV), but, in the case of *P. irritans* (Table VI) no such explanation is possible and we are forced to the conclusion that drought is in some way, perhaps by acting on the instinct to copulate, responsible for an increase in the percentage of fertilized eggs. With *X. cheopis* drought does not seem to have any marked effect on the fertility of eggs (see Table VIII).

Larvae.

This stage may be subdivided into two periods, (1) an active and (2) a quiescent or resting phase, passed within the cocoon.

In the present work the second or resting period has, for convenience, been treated under a joint heading with the cocoon stage. For such treatment, there is some justification, for no genuine metamorphic stages could be more sharply separated from one another as regards power of resisting unfavourable conditions and death than are the periods of active and resting larval life respectively. The range of conditions which the active larvae are fitted to surmount is a narrow one, but, once within the cocoon, the species studied can easily tide over dangers that would mean 100 % mortality in the active stage.

Reference to Table XXV will show that in the dry incubators (75° F. and 84° F. and humidity ·60) and warm cupboard (67°—69° F. and humidity ·65—·71) active larvae of *P. irritans*, as well as of *C. fasciatus* and *X. cheopis*, died, while in the cocoon stage some survived. The fact that in these dry situations the majority of the insects which died in the cocoons were in the larval stage suggests that the transference of cocoons took place without allowing a sufficient interval of time to elapse after spinning.

In the case of all the species investigated, the newly hatched larvae were able to live from several days to over a month without food, provided the conditions were not otherwise unfavourable. Given food and reasonable conditions of temperature, the next important requirement is as high a percentage of moisture in the air as is compatible with surroundings so dry that there is no danger of a wet skin. Local moistening by the urination of animals or sweat from their bodies may convert what would otherwise be an impossible place into a favourable situation; while draughty conditions, with a comparatively high humidity, may be less favourable than a drier situation with a nearly still atmosphere[1].

Evidence has been found of a difference in the kind of food necessary for *C. fasciatus* on the one hand and *P. irritans* and *X. cheopis* on the other. That the faeces of the adult fleas are a possible diet and favourable for the larvae of all three species has been proved. At the same time there is some evidence which points to this food being a necessity for *C. fasciatus.* This divergence in the matter of food among larvae of the different species is consistent with the habits of the parents and the parental host.

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[1] This point may be of importance, as well ventilated houses will be far less suitable for flea-breeding than ill ventilated ones.

The active larval period of *C. fasciatus* is not necessarily one of steady growth or continuous feeding, as larvae have been found from several days to two or three weeks after hatching without any appreciable increase in size. Even when full growth is attained a period of apparently unnecessary delay, or "lagging," sometimes occurs before the spinning of the cocoon is commenced (see Table XXVI). This mode of lengthening the larval stage probably occurs also with *P. irritans,* and possibly with *X. cheopis* as well.

The time occupied by the active larval period is subject to very wide variation, ranging from 15 to 114 days for *C. fasciatus* (Table XVI), 9 to 202 days for *P. irritans* (Table XXI), 12 to 84 days for *X. cheopis* (Table X), and 11 to 142 for *Ct. canis* (Table XXIV). Although low temperature is responsible for the instances of very protracted active life, the question of temperature is not the sole factor determining the length of the period elapsing between the hatching of the egg and the spinning of the cocoon, for marked individual variations occur in this respect between larvae from the same batch of eggs, reared under identical conditions.

Cocoons.

The duration of the cocoon period varied from 8 days to well over a year for *C. fasciatus* (Table XXVIII), from 7 to 239 days for *P. irritans* (Table XXXVIII), from 7 to 182 days for *X. cheopis* (Table XXXV), and from 7 to 354 days for *Ct. canis* (Table XL).

The question of how much of this period is spent as a larva, how much as a pupa and how much as a flea awaiting some stimulus to make it emerge, is no easy matter to determine. It is certain that *C. fasciatus* will rest for long periods as a larva—I have records up to 600 days. With the other species, however, the matter is far from being definitely settled. The observations indicate that the resting stage of *Ct. canis* is generally, if not always, imaginal. In the cases of *P. irritans* and *X. cheopis* the evidence is less definite but points to a rest in the imaginal state before emergence, when this is long delayed. I am of opinion, however, that a considerable period of the time elapsing between the spinning of cocoons and emergence is passed in the larval condition. I have no evidence that the pupal period is ever utilized for resting. So far as can be ascertained, the development in the pupa, though delayed by cold and hastened by heat, is continuous until the pupal envelope is shed.

The length of the cocoon period is largely determined by conditions of temperature, but the range of variation, under exactly similar conditions, was found to be very considerable.

There is some evidence that a fall in temperature during larval life predisposes both *X. cheopis* (see Tables XXXIV and XXXV) and *P. irritans* (see pp. 537, 538) to lengthen their cocoon period. The results of the experiments with *C. fasciatus* (Table XXXII (*b*)) do not suggest that this happens in the case of this species. Table XXXIII, however, shows a predisposition on the part of November batches of larvae of this species to rest longer in the cocoon stage, apart from the actual condition of temperature obtaining at the time the cocoons were spun.

The cocoons of different species differ both in shape and texture, but the outward appearance is largely dependent upon the material in which the larvae live, fragments of which become attached during the spinning. The cocoons of *C. fasciatus* vary greatly as regards the texture and quality of the silk used, some being frail and loose, others as hard and brittle as though composed of glue rather than silk. There is good reason to conclude that hard cocoons are associated with lengthy resting periods (see pp. 610—612).

Ct. canis shows a strong disposition to spend the winter in the cocoon stage. In the case of *P. irritans* there is the same tendency, but it is less obvious, individuals continuing to emerge throughout the winter, if the weather is mild. *C. fasciatus* also frequently passes the cold weather in the cocoon, and a certain proportion of individuals of this species are in the habit of aestivating during the hot months and emerging during the cooler weather of autumn. In hot climates this habit might easily afford a basis for selective action and the consequent production of a race composed of individuals, displaying on the one hand a quick, and on the other greatly delayed, emergence without intermediate types. That this is a strongly ingrained habit is suggested by the emergence of individuals after periods of 100 to 150 days in the cocoon, at a temperature of from 75° F. to 85° F. Even at 93° to 95° F. a certain number of *C. fasciatus* are able to survive as resting larvae for periods of four months and then successfully complete their metamorphosis if removed to a lower temperature (p. 606).

Although with all the species the periods of feeding as larvae and of resting in cocoons are prolonged as the temperature falls, the optimum varies in the different species, being 5° higher for *P. irritans* and 15° to 20° higher for *X. cheopis* than for *C. fasciatus*.

Individual variation, as regards the time taken by these larval and cocoon stages, ensures the spreading of the adult emergence of rat and human fleas over a very wide interval of time. In the case of *Ct. canis* there would seem to be much more restriction for any one brood, although, with this species, some individuals of a brood emerging in autumn will, under suitable conditions, lie over the winter in their cocoons. It is evident that the protection afforded by the cocoon would be the means of saving this species from extermination, not only under conditions of drought (Table XLIV), but also under circumstances of excessive moisture, for it was proved that, in this stage, actual inundation could be survived for at least 12 hours.

Adults.

At 45°—50° F. with nearly saturated air, fleas can live for many days unfed; specimens of *P. irritans* have survived for 125 days, *C. fasciatus* for 95 days, *X. cheopis* for 38 days, *Ct. canis* for 58 and *C. gallinae* for 127 days (see Tables XLV, XLVIII and L). Yet under what might for insects be considered only moderately unfavourable conditions of temperature and humidity their powers of endurance are but slight in the absence of food. *X. cheopis* is little, if any, better fitted than *C. fasciatus* to withstand heat and drought in the absence of a host, but its habit of living on the rat rather than in its bed enables this species to extend the period of its active existence both in time and space and renders it a far more dangerous agent in the spread of plague.

Although kept in a box, if fed on their natural host, *P. irritans* may live for upwards of 513 days (Table LIV), *C. fasciatus* for 106 (Table LV) and *X. cheopis*, fed on man, for 100 (Table LVI). It is probable that both rat fleas, under natural circumstances, would live longer. *Ct. canis* and *C. gallinae* have lived for periods of 234 and 345 days respectively (Table LVII) when fed on man, and it is unlikely that they have a less lengthy life when fed on dogs or fowls.

In view of the suggestion that adult fleas imbibe fluids other than blood, some experimental tests were undertaken. Dissections were made, after an opportunity had been given the fleas to imbibe coloured fluids, but no sign of the insects having fed could be traced. Among the observations on record, which suggest that adult fleas can be nourished otherwise than by warm-blooded animals, are those in which sick flies and Lepidopterous larvae are said to have been attacked[1]. I have made experiments with *C. fasciatus* and *Tenia fenestrella*. The results were negative and the fleas died as soon as the controls. The opinion I have formed as a result of my own experience is that feeding on warm blooded animals is essential to reproduction.

Most, if not all, the species dealt with have been observed to copulate shortly after emergence, but no signs of either eggs or brood have been observed in any of the boxes, jars, or other receptacles in which unfed fleas have been kept. Experiments conducted in specially prepared jars, containing food for any larvae that might result, and also abundant cover for the fleas, gave the same result. On the other hand, virgin females of *P. irritans*, when fed, laid freely, though only infertile eggs. In fact, during the course of these experiments, no support whatever has been obtained for the theory that flea breeding can take place from one generation to another in the absence of an animal host to provide food for the adult.

Although the several species of fleas other than human were successfully fed on man and lived for considerable periods, no eggs were laid by any of the species, save *C. gallinae*, when 15 minutes' daily feeding was permitted.. Later attempts with the hair of the correct host placed in the boxes to afford cover, were also ineffective, but feeding for longer than 15 minutes daily, was sufficient to keep *P. irritans* laying freely and fertile eggs were also obtained from *C. fasciatus* and *X. cheopis*. *Ct. canis* required to be given opportunity to feed for from 5 to 12 hours' daily to induce egg-laying. While *X. cheopis* feeds on man more readily than *C. fasciatus*, the females do not lay so freely, presumably because, in accordance with this species' practice of living upon its host, rather than in its nest, they require more frequent feeding than *C. fasciatus*.

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[1] The feeding by adult fleas on the larvae of Lepidoptera, noted by Boden (1882), seems to be just within the bounds of possibility, but is probably of rare occurrence. Most, if not all the Lepidopterous larvae, likely to be found in the same habitat as fleas, live in silken galleries, a habit which would afford great protection as the larvae are able to travel rapidly away from any spot where the silken tube may be pierced. The possibility of starving adult fleas attacking larvae of their own species has been specially considered as such a habit might lead to infection of the adult by any bacteria that might be living in the larval gut, and thus have an important bearing on the recrudescence of plague. I made the following trial: A number of unfed adult *C. fasciatus* were divided into two batches and placed in similar tubes and into one only of the tubes a number of flea larvae were placed. The length of life of the fleas in the tube containing the larvae was no longer than that of those in the control, while the larvae remained healthy and spun their cocoons as usual. The constant attention demanded by other work prevented any very close watch being kept on the activities of the fleas and I cannot state if any attempts were made to feed on the larvae.

Russell (1913) makes mention of attacks made by fleas on flies incapable of flight. It seems, however, improbable that this or any other similar food can be a serious factor in tiding the species over periods when no warm blooded hosts are available.

The experiments in which the opportunities offered to adults of *P. irritans* to feed were varied (see p. 641) afforded no evidence that the amount of food taken had any influence on the *fertility* of the eggs laid, but only upon the *number*. This result confirms those obtained when rat and dog fleas were fed on a human host (see p. 479), and shows the great influence upon egg-production of the quantity of food taken by the adult. At the same time it further emphasises the improbability of breeding by unfed fleas.

It has been proved conclusively (p. 637) that male fleas are able to impregnate at least 13 females, and further that the females must pair more than once if the large number of eggs they are able to produce are to be of any service to the species.

It is uncertain whether the individuals that rapidly attain the imaginal stage are long-lived as adults, but it has been proved with regard to *P. irritans* that a long cocoon stage may be followed by a very long life as an adult.

My observations on the maximum duration of the various stages in the life history of *C. fasciatus, X. cheopis, P. irritans, Ct. canis* and *C. gallinae* may be summed up as follows:

C. fasciatus—egg stage 10 days, larval 114, cocoon 450, adult when fed 106, unfed 95.

X. cheopis—egg stage 10 days, larval 84, cocoon 182, adult when fed 100, unfed 38.

P. irritans—egg stage 12 days, larval 202, cocoon 239, adult when fed 513, unfed 125.

Ct. canis—egg stage 8 days, larval 142, cocoon 354, adult when fed 234, unfed 58.

C. gallinae—egg stage 7, larval (estimate) 50, cocoon (interrupted by opening) 70, adult when fed 354, unfed 127.

Adding together the maximum periods recorded for each stage, a fair indication of the possible length of life of the individual from egg until its death as a perfect insect is: for *C. fasciatus* 680 days, *X. cheopis* 376, *P. irritans* 966, *Ct. canis* 738, *C. gallinae* 481.

On this basis, and allowing for the longest recorded *unfed* imaginal lives, it will be seen that there is no difficulty in accounting for active adults being found, in favourable situations, where there have been *no hosts for considerable periods.* We may safely estimate for *C. fasciatus* 22 months, *P. irritans* 19 months, *X. cheopis* 10 months, *Ct. canis* 18 months, *C. gallinae* 12 months.

NOTE.

It is a matter of regret to me that the valuable and interesting paper "Observations on Flea breeding (*X. cheopis*) in Poona" (Report LV of the Advisory Committee, Plague Supplement II, *Journal of Hygiene*, Vol. XI, pp. 300—325) was not available before I had finished the experimental work and the writing of this report.

Notwithstanding the fact that the methods and conditions applying to the two series of experiments were so diverse, the great importance of humidity in controlling egg laying and hatching, the rearing of larvae and the length of the adult life is demonstrated alike by the Poona experiments and those of the present research which were carried out at Loughton, Essex. The Loughton experiments show, in addition, that both high and low temperatures are detrimental to *X. cheopis*, cold being especially fatal to the immature stages, a fact that the equable temperature of Poona tends to conceal.

The striking divergences in detail of the two sets of experiments are as follows, and must, I think, be attributed to the causes given below:

1. *Egg laying.* The much smaller number of eggs per female laid in Loughton must be attributed to the comparatively low temperature at which the cages were kept.

2. *Egg hatching.* The comparison is between ova obtained from excited insects struggling for foothold at Poona and those of individuals more comfortable, if less vigorous owing to the lower temperature, at Loughton. Under the most favourable circumstances only 49·1 % hatched at Poona while the best Loughton record is 76 %.

3. The greater larval mortality and shorter adult life at Poona is probably due partly to the use of methods less favourable to the insects than those employed at Loughton, and partly to a probable greater daily fluctuation of humidity at Poona.

In conclusion, I desire to record my thanks to many friends for their assistance and advice. I wish also to record my indebtedness to my assistant Mr H. J. Turner, for his valuable help and the care with which he entered up the records.

A. W. B.

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DESCRIPTION OF PLATES XXVII—XXXIV.

Plates XXVII—XXIX, photographs of various fleas magnified 30 diameters. (The specimens are treated with hot 20 $^0/_0$ caustic potash for a few minutes, dehydrated in alcohol, cleared in xylol and mounted in balsam.)

Plate XXVII.	Fig. 1.	*Ceratophyllus fasciatus*, ♂.
	,, 2.	,, ,, ♀.
	,, 3.	*Leptopsylla musculi*, ♂.
	,, 4.	,, ,, ♀.
Plate XXVIII.	Fig. 1.	*Pulex irritans*, ♂.
	,, 2.	,, ,, ♀.
	,, 3.	*Xenopsylla cheopis*, ♂.
	,, 4.	,, ,, ♀.
Plate XXIX.	Fig. 1.	*Ctenocephalus canis*, ♂.
	,, 2.	,, ,, ♀.
	,, 3.	,, *felis*, ♂.
	,, 4.	,, ,, ♀.
Plate XXX.	Fig. 1.	Ova, *Xenopsylla cheopis*, × 30.
	,, 2.	,, *Pulex irritans*, × 26.
	,, 3.	,, *Ceratophyllus fasciatus*, × 26.
	,, 4.	,, *Ctenocephalus canis*, × 30.
Plate XXXI.	Fig. 1.	Ova, *Pulex irritans*, × 60.
	,, 2.	Skin of full-grown larva of *Ceratophyllus fasciatus*, × 17, showing the arrangement of dorsal plates and hairs.
	,, 3.	Head of *Xenopsylla cheopis*, × 90, showing the epipharynx and mandibles the elements which together form the piercing and sucking tube and beneath these the labium. The maxillary palps are in a drooping position.
Plate XXXII.	Living larvae, × 10.	
	Fig. 1.	Dorsal, lateral and ventral aspects, *Xenopsylla cheopis*.
	,, 2.	Lateral aspect, *Ceratophyllus fasciatus*.
	,, 3.	In natural surroundings seen from above, *Xenopsylla cheopis*.
	,, 4.	Lateral aspect, *Pulex irritans*.
Plate XXXIII.	Fig. 1.	Cocoons of *Xenopsylla cheopis*, × 10.
	,, 2.	,, *Pulex irritans*, × 10.
	,, 3.	,, *Ceratophyllus fasciatus*, × 10.
	,, 4.	,, *Leptopsylla musculi*, × 10.
Plate XXXIV.	Fig. 1.	Pupae of *Xenopsylla cheopis*, ♂ and ♀, living, × 10.
	,, 2.	,, *Ctenocephalus canis*, ♀, living, × 16.
	,, 3.	,, *Leptopsylla musculi*, ♀, living, × 16.
	,, 4.	Cocoons of *Ctenocephalus canis*, × 10.

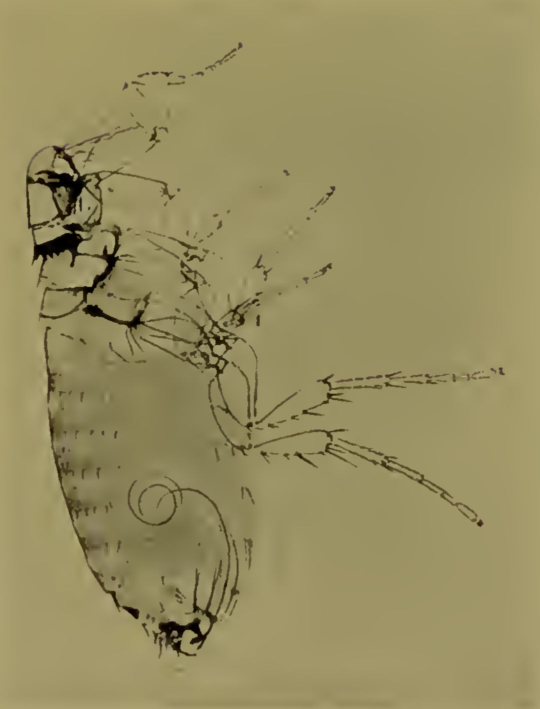

Fig. 1. *Ceratophyllus fasciatus* ♂ × 30.

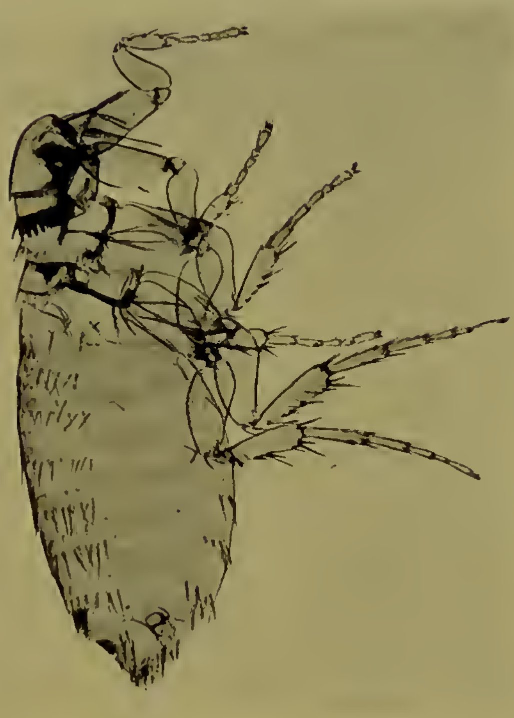

Fig. 2. *Ceratophyllus fasciatus* ♀ × 30.

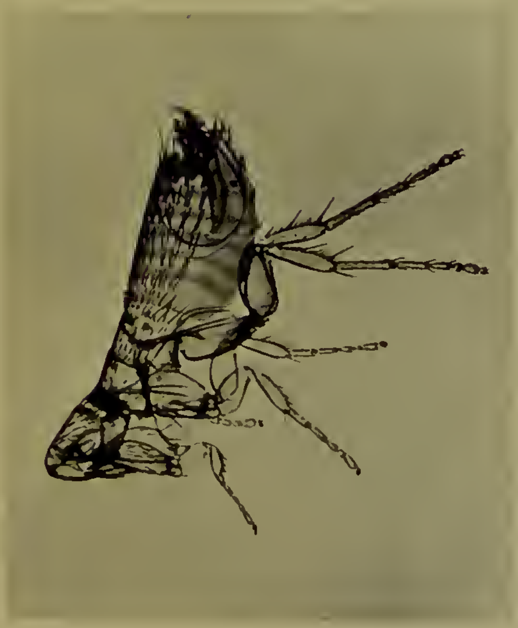

Fig. 3. *Leptopsylla musculi* ♂ × 30.

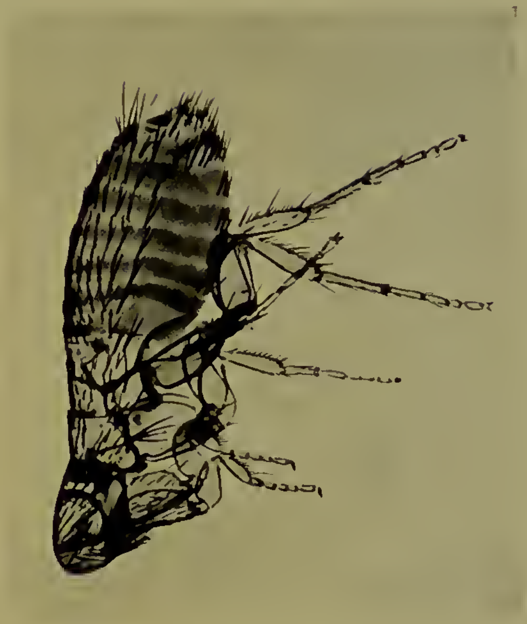

Fig. 4. *Leptopsylla musculi* ♀ ×30.

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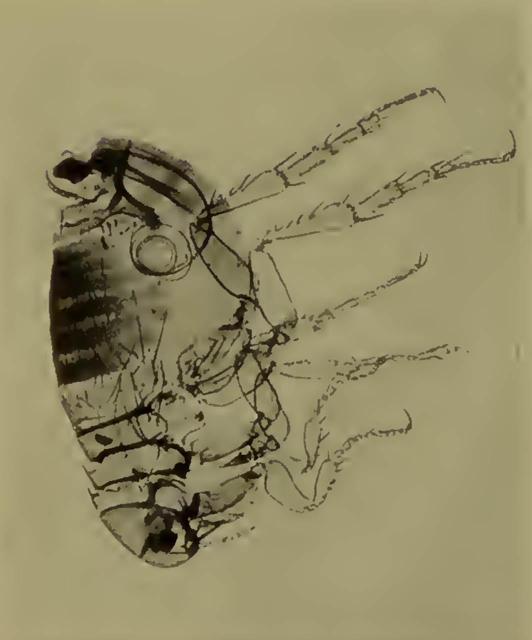

Fig. 1. *Pulex irritans* ♂ × 30.

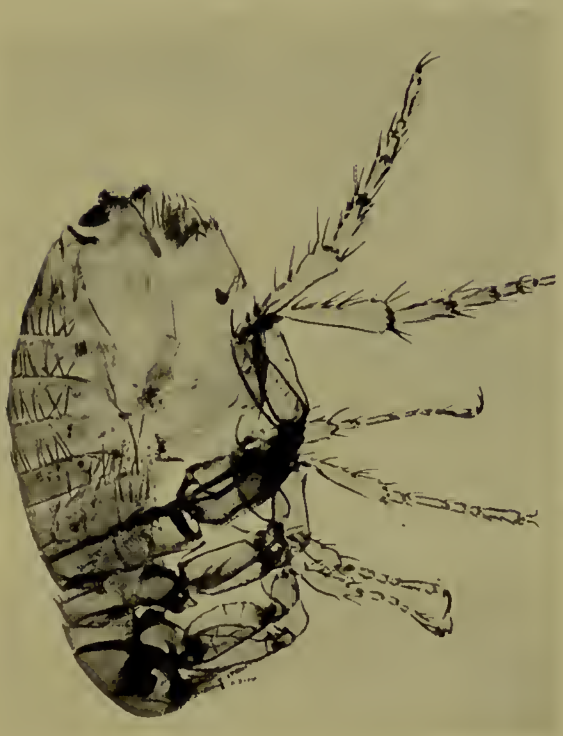

Fig. 2. *Pulex irritans* ♀ × 30.

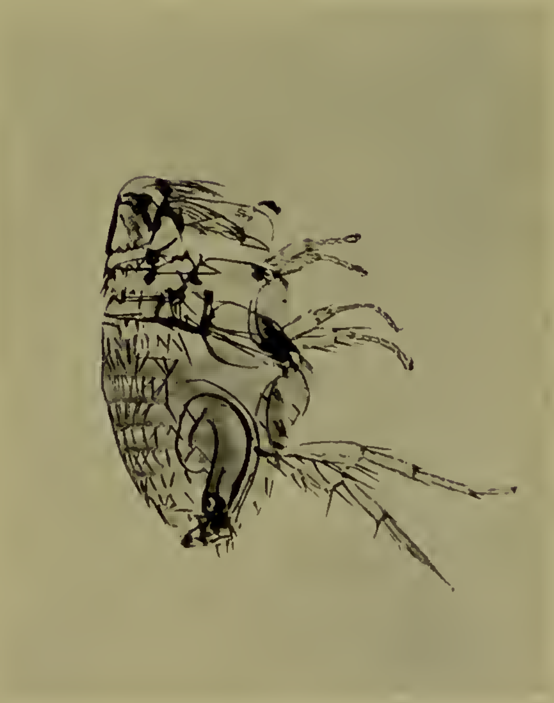

Fig. 3. *Xenopsylla cheopis* ♂ × 30.

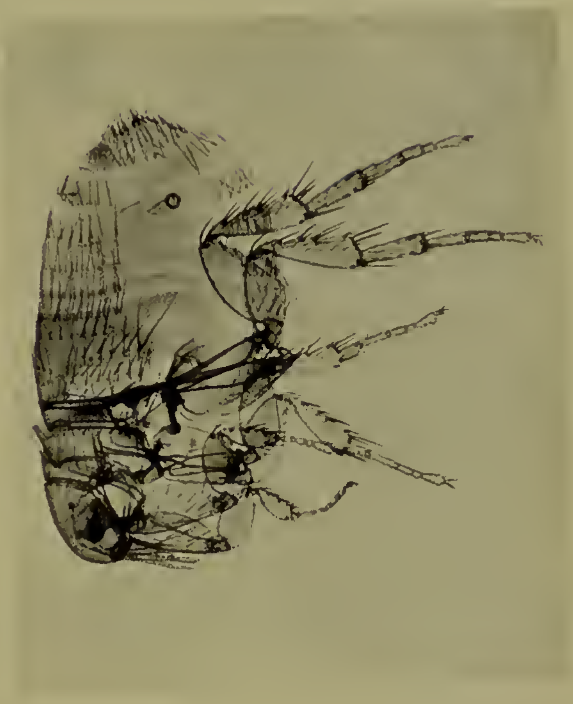

Fig. 4. *Xenopsylla cheopis* ♀ × 30.

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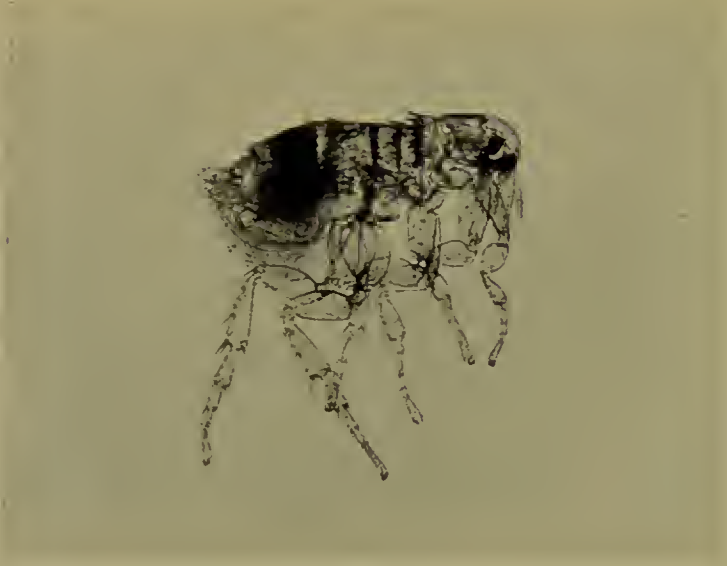

Fig. 1. *Ctenocephalus canis* ♂ × 30.

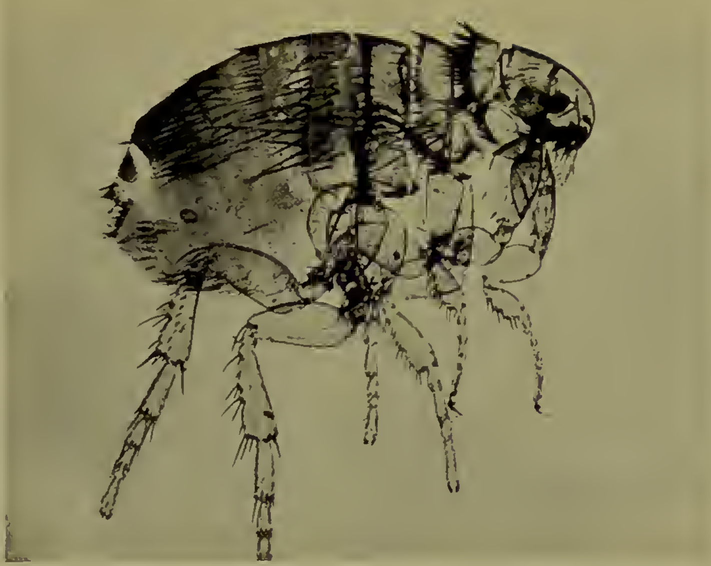

Fig. 2. *Ctenocephalus canis* ♀ × 30.

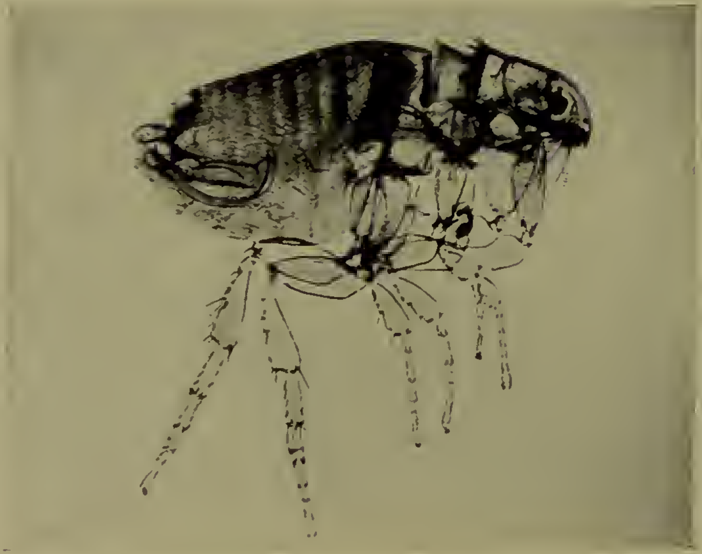

Fig. 3. *Ctenocephalus felis* ♂ × 30.

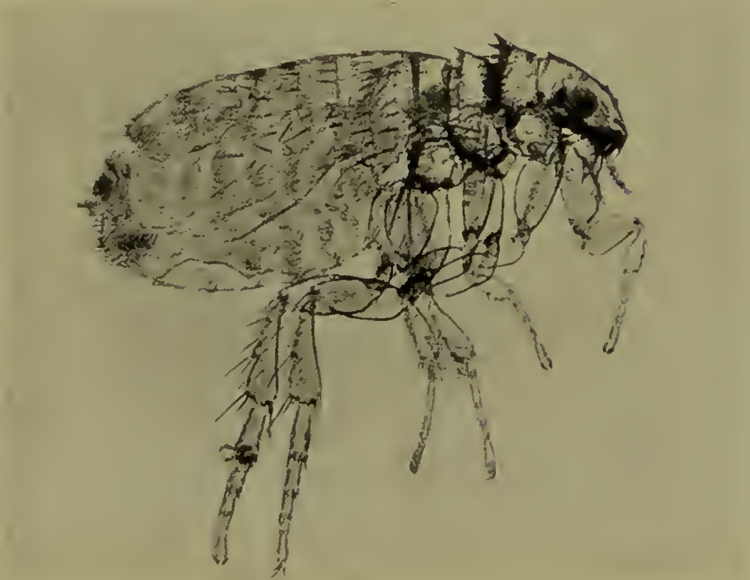

Fig. 4. *Ctenocephalus felis* ♀ × 30.

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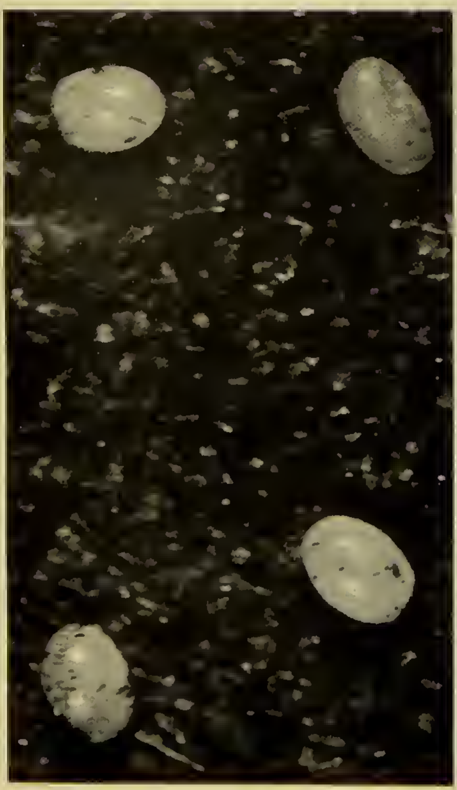

Fig. 1. Ova of *Xenopsylla cheopis* × 30.

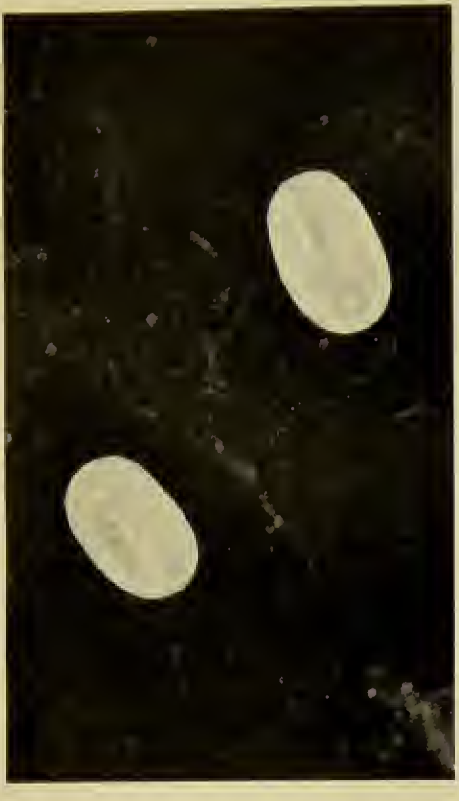

Fig. 2. Ova of *Pulex irritans* × 26.

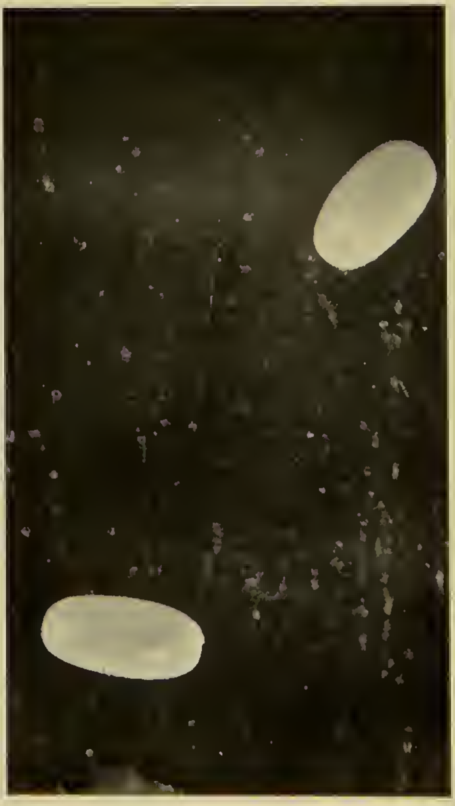

Fig. 3. Ova of *Ceratophyllus fasciatus* × 26.

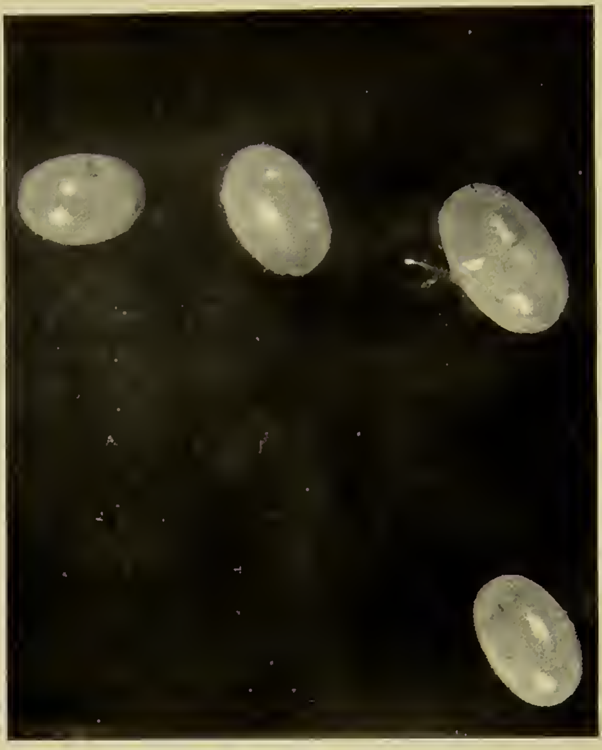

Fig. 4. Ova of *Ctenocephalus canis* × 30.

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PLATE XXXI

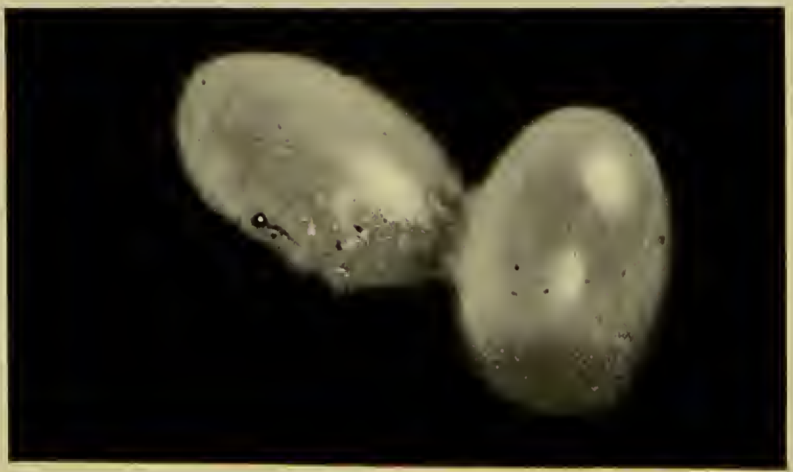

Fig. 1. Ova of *Pulex irritans* × 60.

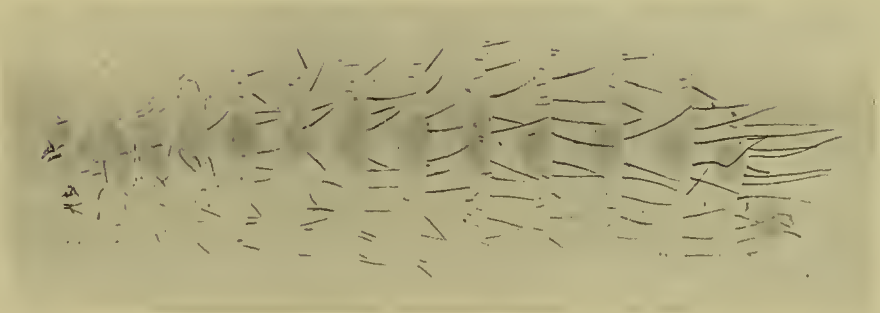

Fig. 2. Skin of full grown larva of *Ceratophyllus fasciatus* × 17. Showing arrangement of dorsal plates and hairs.

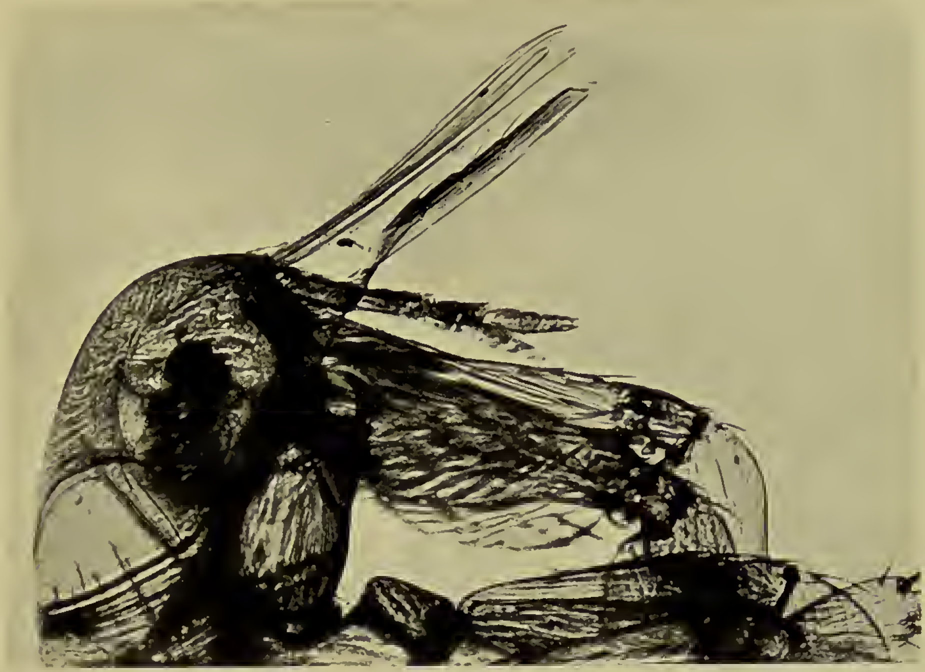

Fig. 3. Head of *Xenopsylla cheopis* ♀ × 90.

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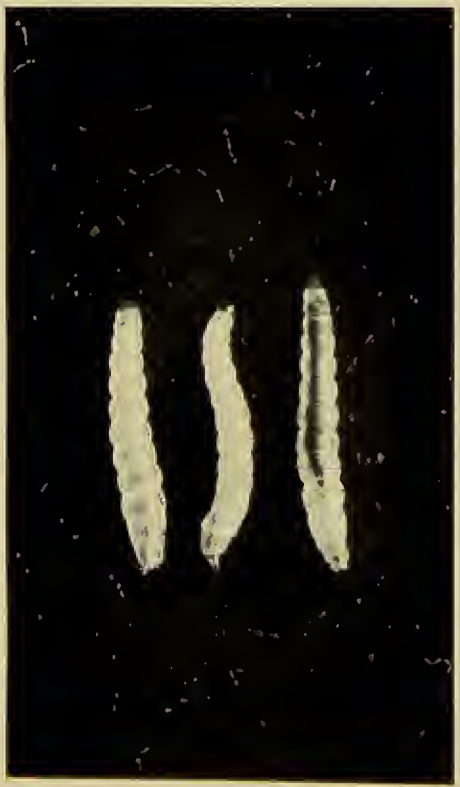

Fig. 1. Dorsal, lateral and ventral aspects of larvae of *Xenopsylla cheopis* × 10.

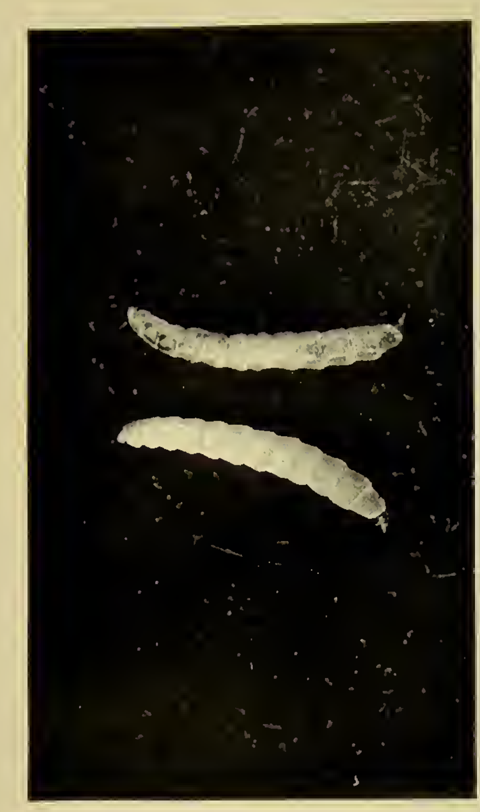

Fig. 2. Larvae of *Ceratophyllus fasciatus* × 10.

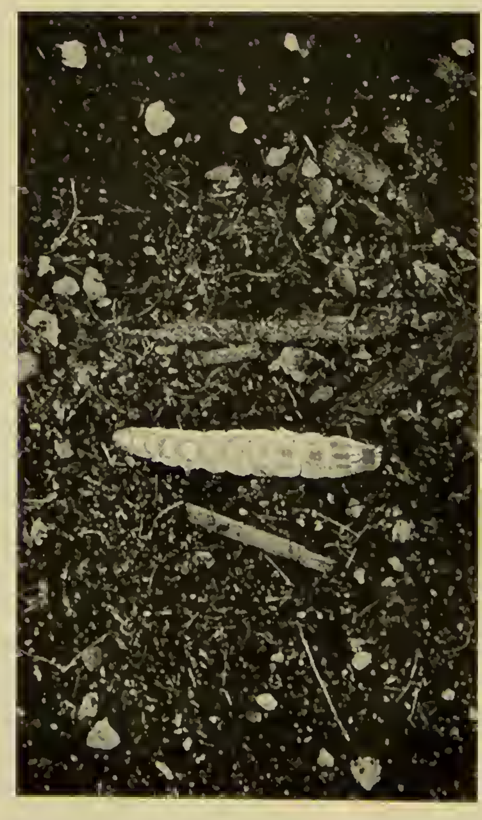

Fig. 3. Larva of *Xenopsylla cheopis* in natural surroundings × 10.

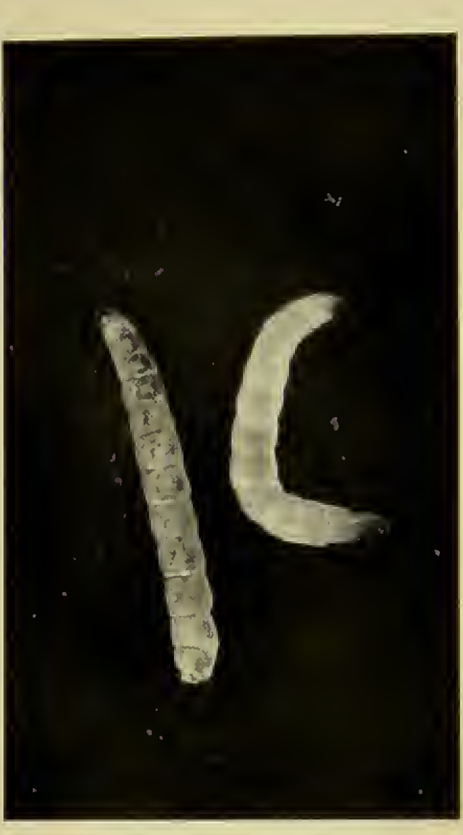

Fig. 4. Larvae of *Pulex irritans* × 10.

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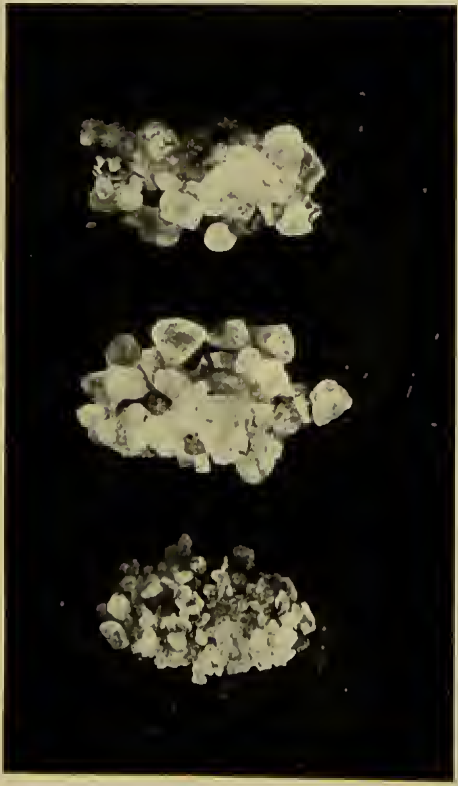

Fig. 1. Cocoons *Xenopsylla cheopis* × 10.

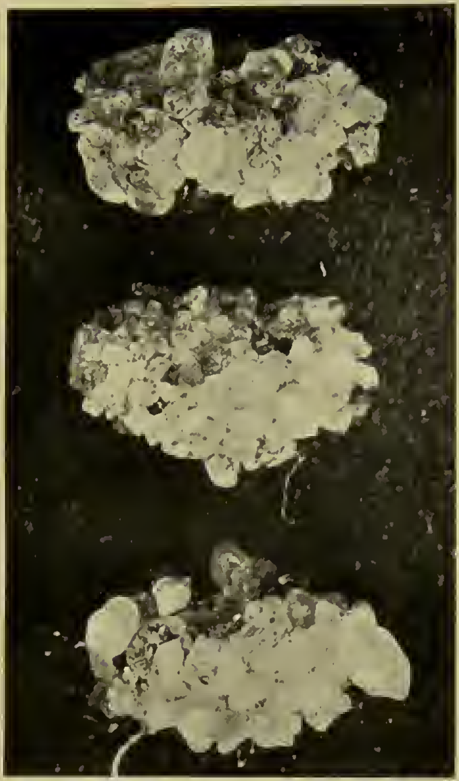

Fig. 2. Cocoons *Pulex irritans* × 10.

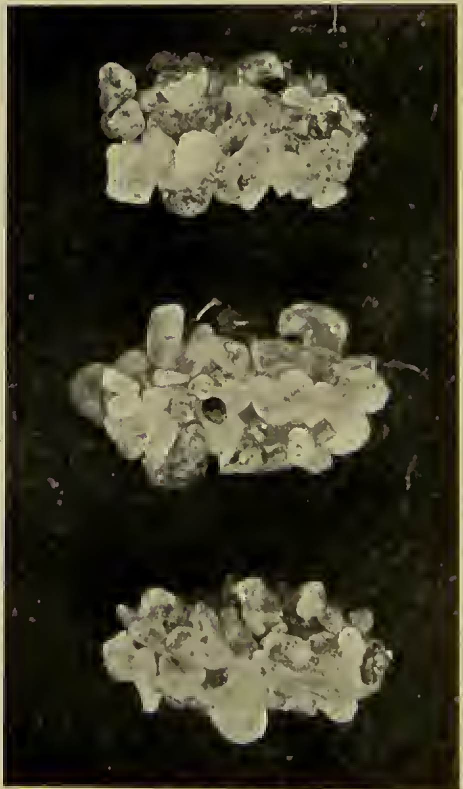

Fig. 3. Cocoons *Ceratophyllus fasciatus* × 10.

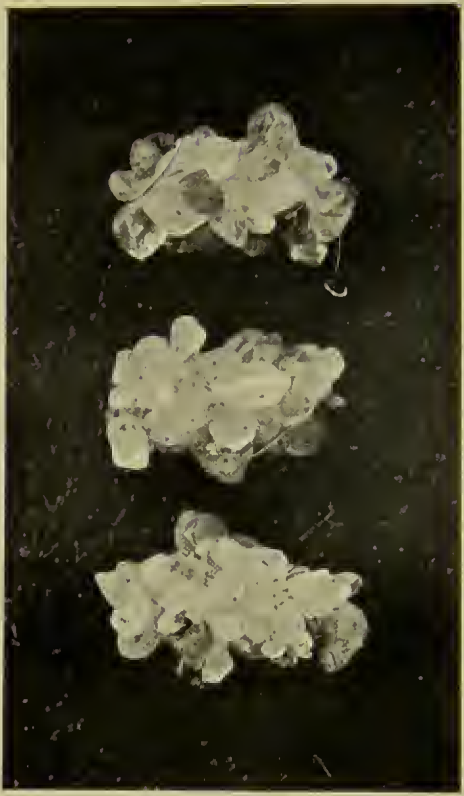

Fig. 4. Cocoons *Leptopsylla musculi* × 10.

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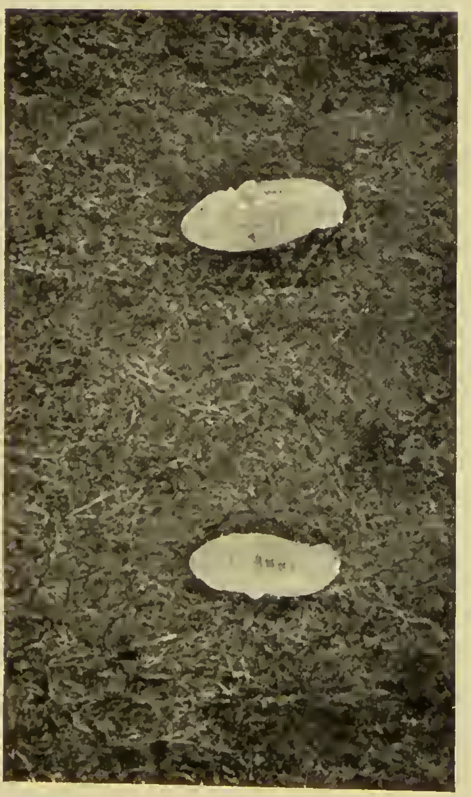

Fig. 1. ♂ and ♀ pupae of *Xenopsylla cheopis* × 10.

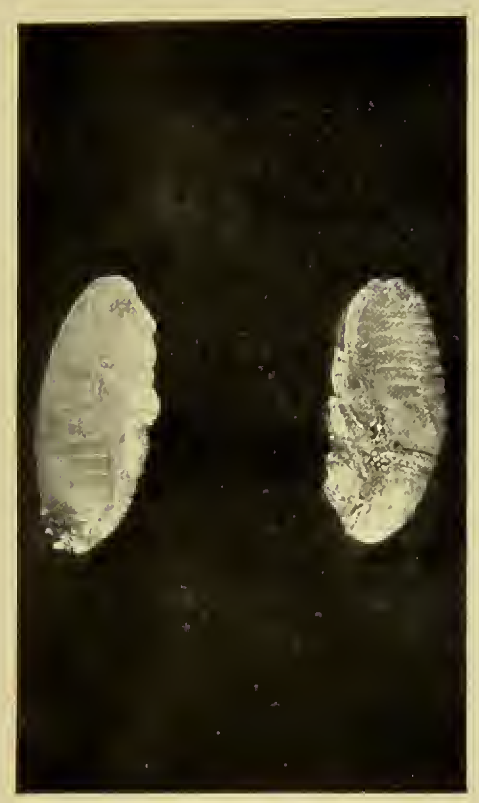

Fig. 2. Pupae of *Ctenocephalus canis* × 16.

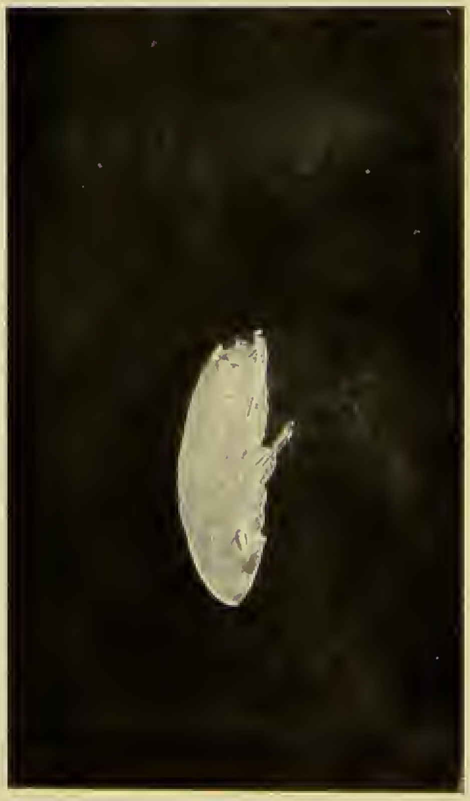

Fig. 3. Pupa of *Leptopsylla musculi* × 16.

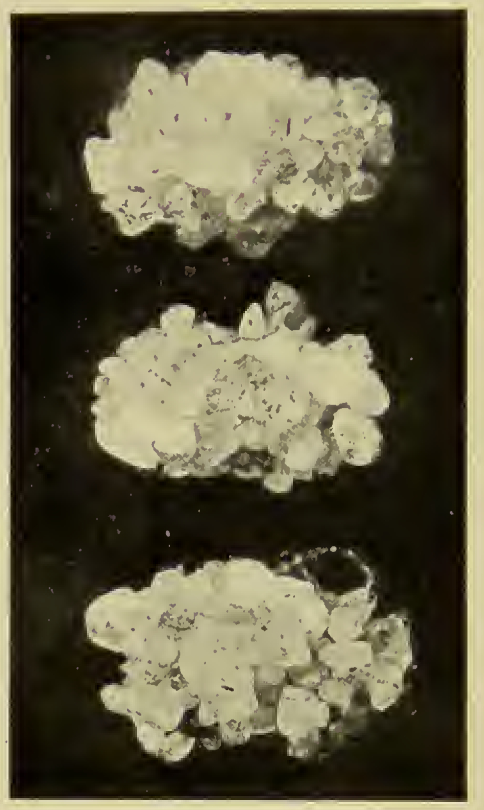

Fig. 4. Cocoons of *Ctenocephalus canis* × 10.

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